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THE MEAN WINDS OF THE UPPER TROPOSPHERE
OVER THE CENTRAL AND EASTERN PACIFIC

James C. Sadler

Hawaii University

Prepared for:

Environmental Prediction Research Facility (Navy)

June 1972

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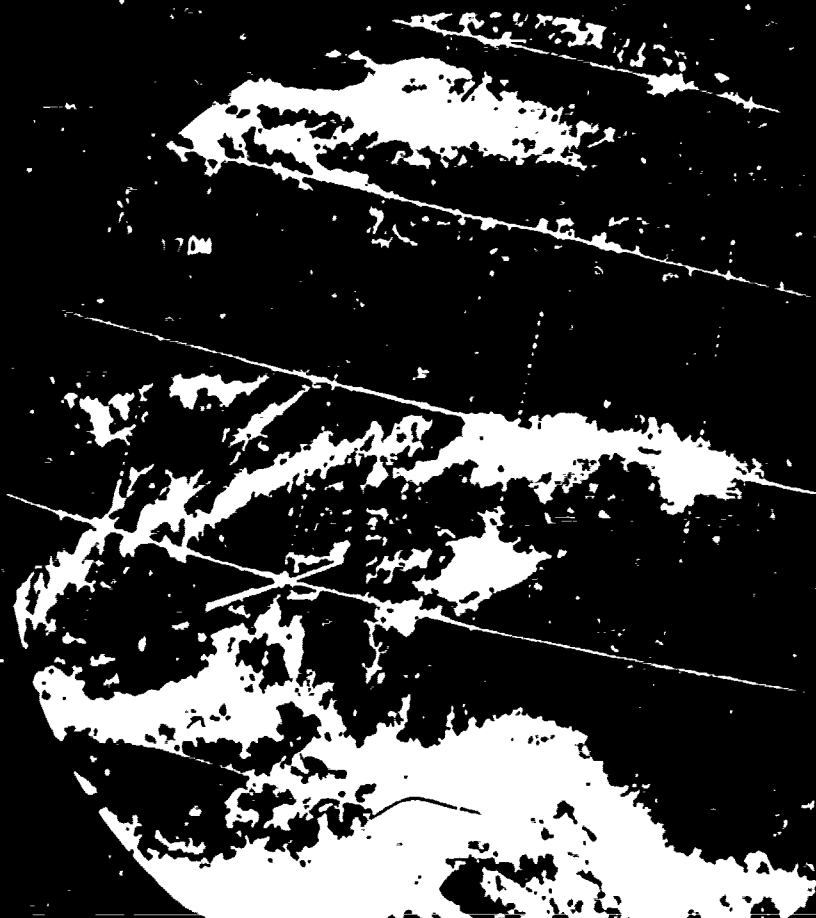
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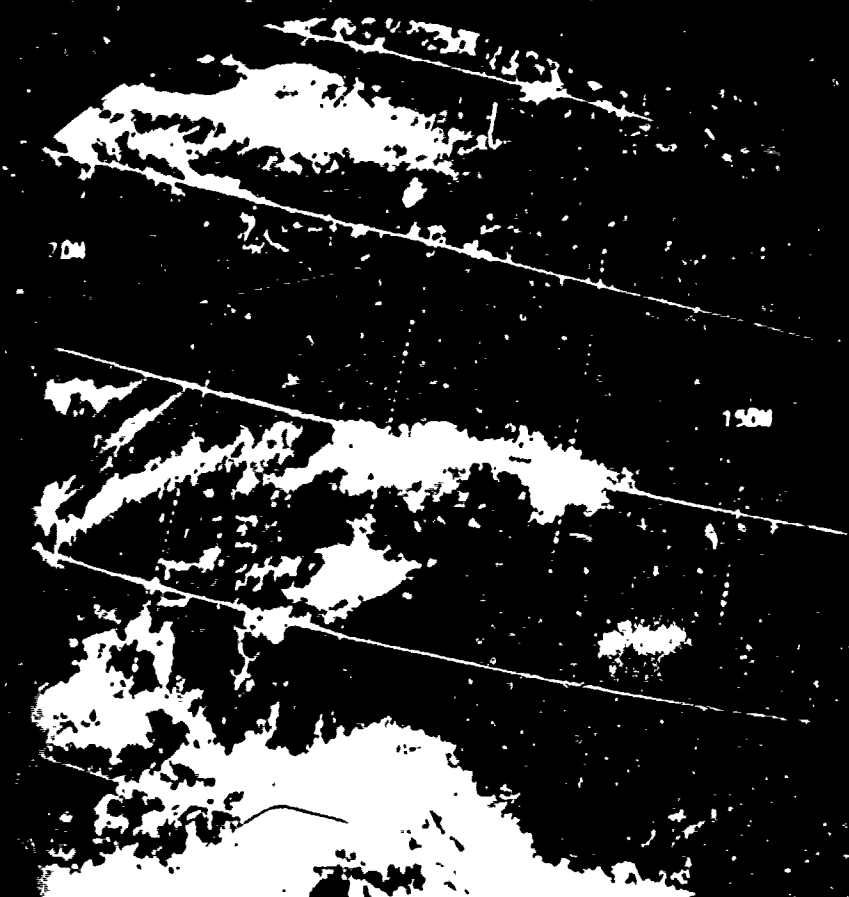
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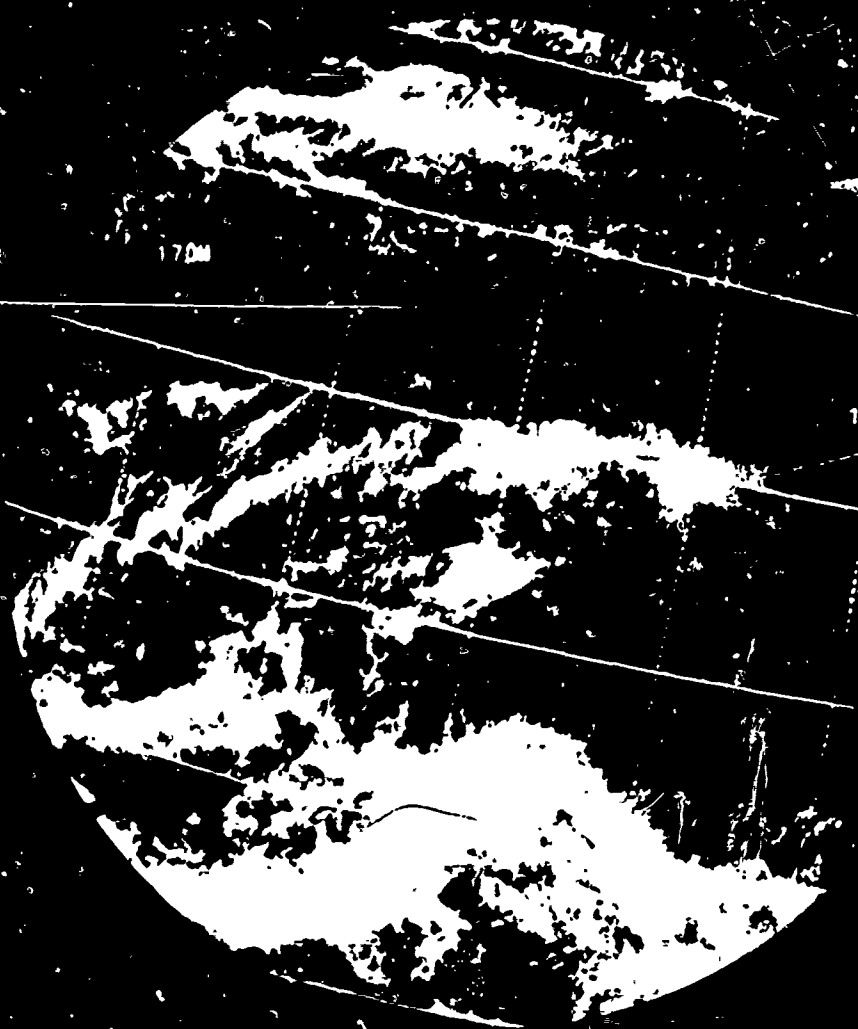
THE MEAN WINDS OF THE UPPER OVER THE CENTRAL AND EAST



ENVPREDRSCHFAC
Technical Paper No. 8-72

WINDS OF THE UPPER TROPOSPHERE CENTRAL AND EASTERN PACIFIC





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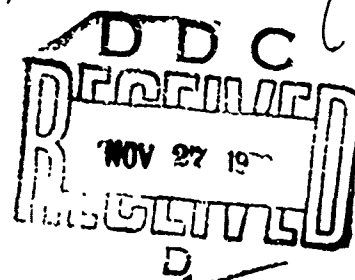
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University of Hawaii

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ABSTRACT

Analyses of mean monthly upper-tropospheric winds for the 200-, 250- and 300-mb levels are presented for the eastern and central Pacific region. Analyses are based on 9 years of PIREP winds measured on commercial jet aircraft as well as rawins from fixed stations. The upper troposphere is discussed in terms of its major features and their changes from month to month.

IR

1. INTRODUCTION

The use of electronic navigation equipment has improved the general quality of aircraft wind observations (PIREP winds). The bulk of the observations for the past decade has been concentrated at the jet aircraft flying levels between 30,000 and 40,000 ft. These data have been used in calculating mean-monthly flow over tropical regions where data from fixed stations are extremely sparse. Pearson (1968) has used two years (1962 and 1963) of data from transequatorial flights to produce mean-monthly wind analyses over portions of the central and eastern Pacific. Additionally, averaged aircraft wind reports have been used in preparing the International Indian Ocean Expedition Meteorological Atlas (Ramage and Raman, 1972). In the Atlantic averaged PIREPS have been used in monthly streamline analyses (Aspliden, et al., 1966).

This atlas utilizes the PIREP winds from the first nine years of the commercial jet aircraft age in conjunction with radiowinds and radarwinds (rawins) from fixed stations to define the upper-troposphere wind climatology of the central and eastern Pacific Ocean.

2. DATA

2.1 Winds from PIREPS

Aircraft wind reports at 28,000 ft and above, for the area 30S to 50N between 155E and 120W for the period 1960-1968 were extracted from the manuscript maps of the National Weather Service at Honolulu Airport. These were supplemented east of 120W with data extracted from flight logs of the Canadian Pacific and UTA airlines. Monthly mean resultant winds were computed for each 5 degree latitude-longitude grid square and located at the averaged position of the reports. Wind steadiness* and percentage of observations with an easterly wind component were computed to aid in analysis and interpretation. The data are homogeneous in neither time nor space. With

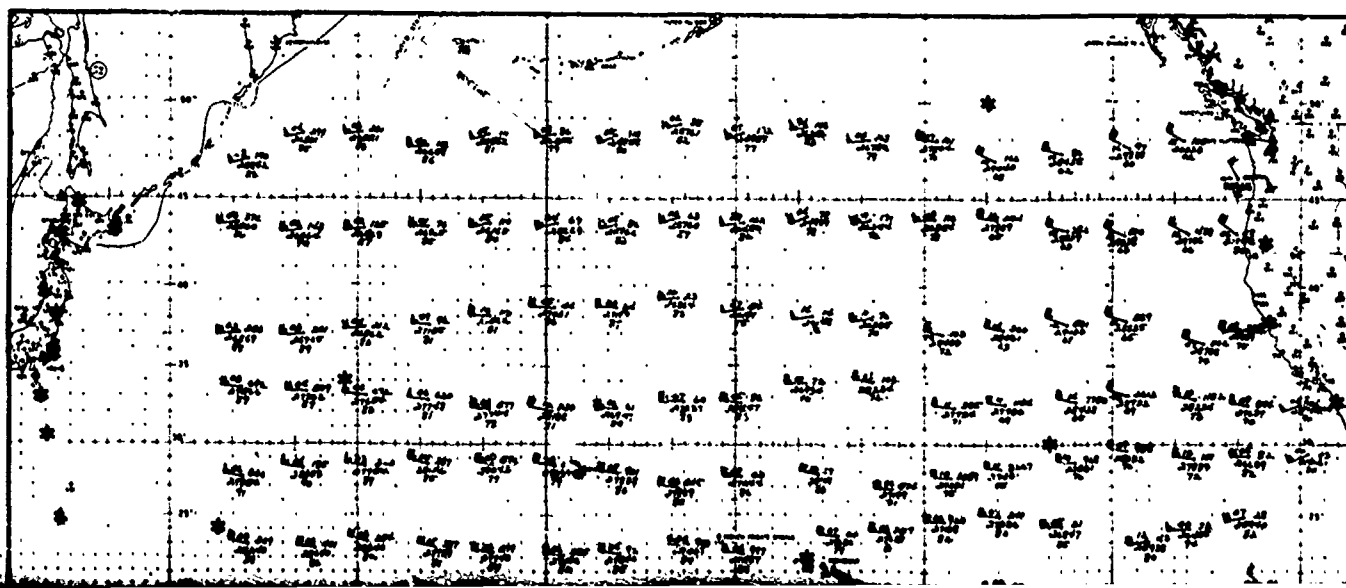
each succeeding year the average flight level. traveled air routes. The coast of the United States other route. The month A typical monthly distr

Four sets of month. All altitudes were then stratified by heightory constant pressure 28,000-32,000 ft (300 m and above (200 mb).

2.2 Rawins

Updated summaries land and ship stations and along the west coast the summaries covered stations not listed in obtained from various sources stations, including the Society, Tuamotu, and Marshall Daily Weather Bulletins Summaries for the Pacific Midway, the islands of States except those also National Climatic Data Center correspond in time to the lengths of record during

* Wind steadiness = $\frac{\text{mean resultant wind speed}}{\text{mean wind speed}} \times 100\%$.



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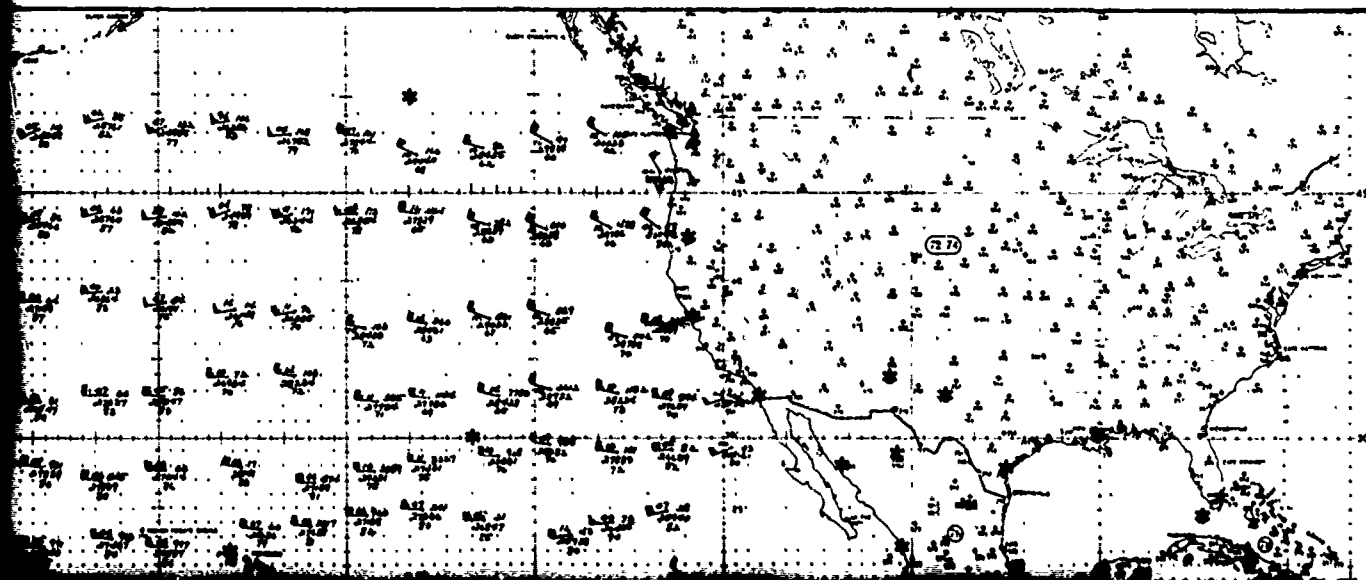
100%.

each succeeding year the number of observations increased as did the average flight level. Observations are concentrated along heavily traveled air routes. The corridor between Honolulu and the west coast of the United States has about triple the data volume of any other route. The monthly data sample averages near 75,000 observations. A typical monthly distribution of data is shown in Figure 1.

Four sets of mean resultant winds were determined for each month. All altitudes were first composited. The observations were then stratified by height intervals to mesh with the rawins at mandatory constant pressure surfaces. The stratification intervals were: 28,000-32,000 ft (300 mb); 33,000-36,000 ft (250 mb); and 37,000 ft and above (200 mb).

2.2 Rawins

Updated summaries of wind data were prepared for most fixed land and ship stations over the ocean area, Mexico, Central America, and along the west coasts of South and North America. Where possible, the summaries covered the same period as the PIREP data. Data for stations not listed in "Monthly Climatic Data for the World" were obtained from various other sources. Data for most Southern Hemisphere stations, including the newly established French stations in the Society, Tuamotu, and Marquesas Islands, were extracted from the Daily Weather Bulletins of the New Zealand Meteorological Service. Summaries for the Pacific islands of Eniwetok, Kwajalein, Canton, and Midway, the islands of the Caribbean, and all stations in the United States except those along the west coast were obtained from the National Climatic Center (Asheville, North Carolina) and do not correspond in time to the period of the PIREPS. They are for varied lengths of record during the period 1945-1962.



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$$\text{Wind steadiness} = \frac{\text{mean resultant wind speed}}{\text{mean wind speed}} \times 100\%.$$

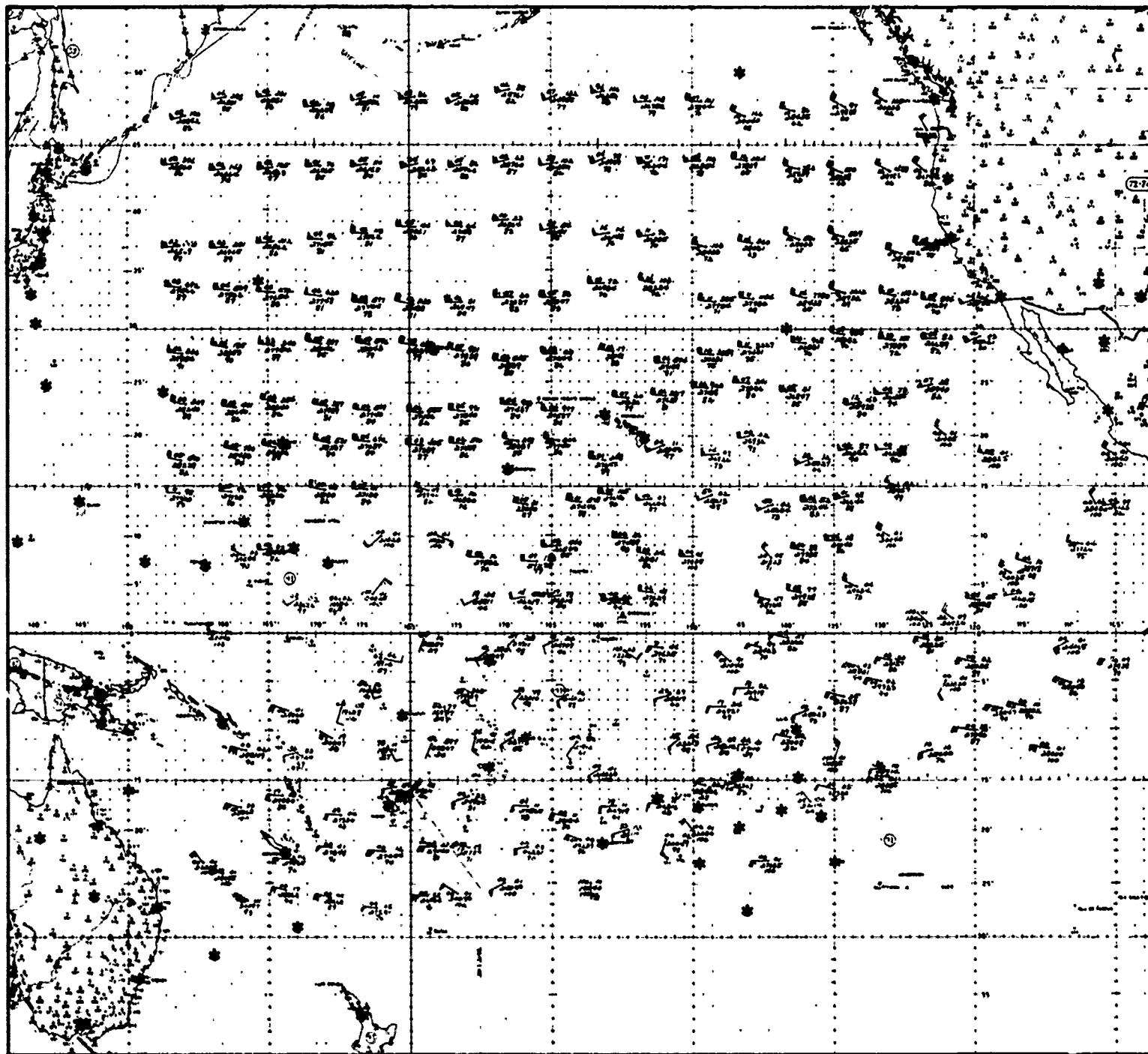
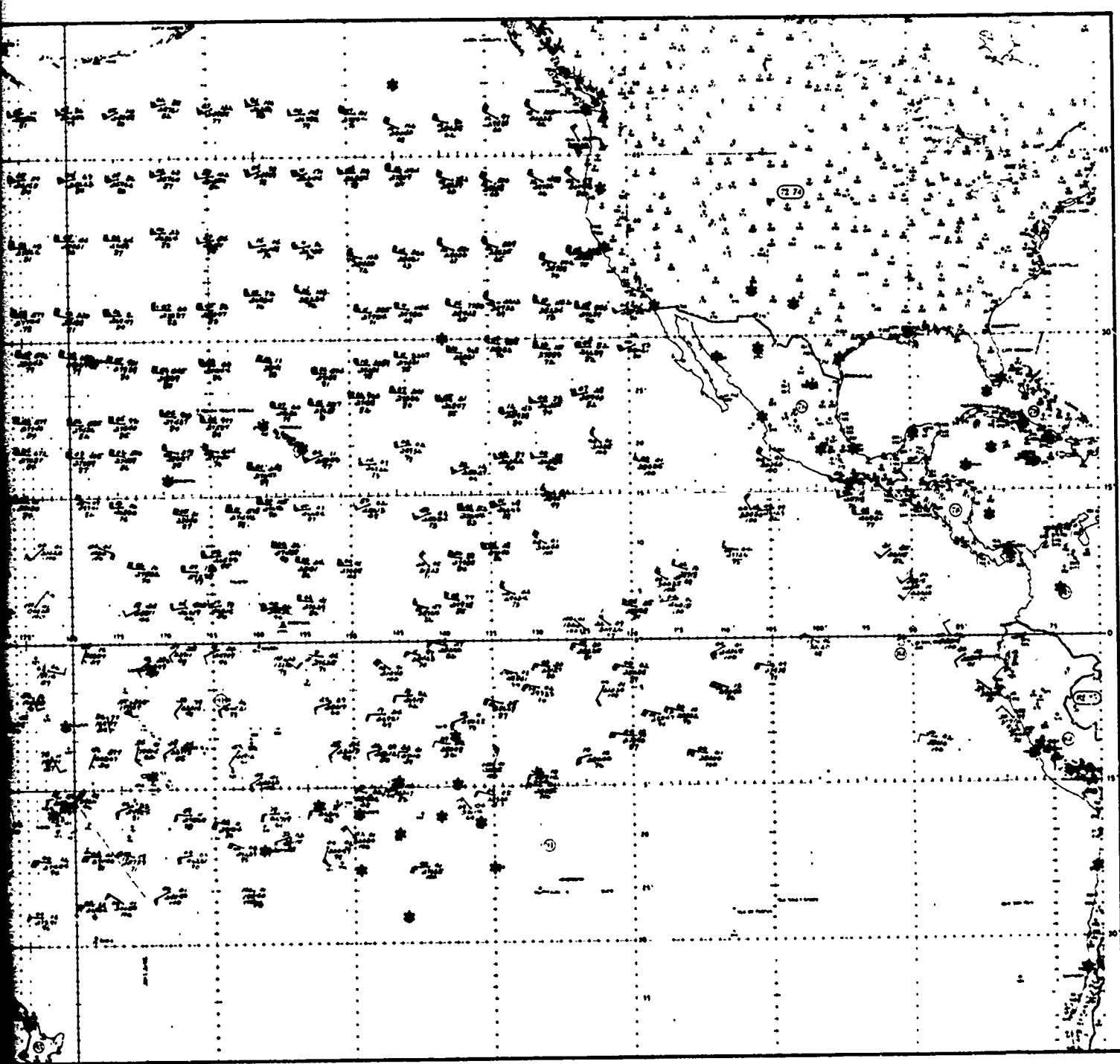


Figure 1. Typical monthly composite of aircraft reports. Asterisk symbol denotes location of rawinsonde

east of 120W with data
 on Pacific and UTA airlines.
 for each 5 degree latitude-
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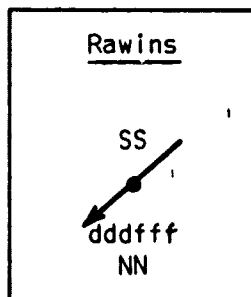
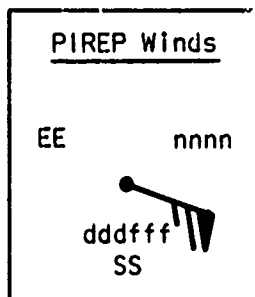
States except those along the west coast were obtained from the
 National Climatic Center (Asheville, North Carolina) and do not
 correspond in time to the period of the PIREPS. They are for varied
 lengths of record during the period 1945-1962.

speed x 100%.



posite of aircraft reports. Asterisk symbol denotes location of rawin stations.

2.3 Plotting Models



- EE -percentage of winds with an east component
- nnnn -number of observations
- ddd -mean resultant wind direction
- fff -mean resultant wind speed in knots (flag = 50 knots, long barb = 10 knots, short barb = 5 knots)
- SS -steadiness of winds in percent
- NN -number of years of record

3. TERMINOLOGY

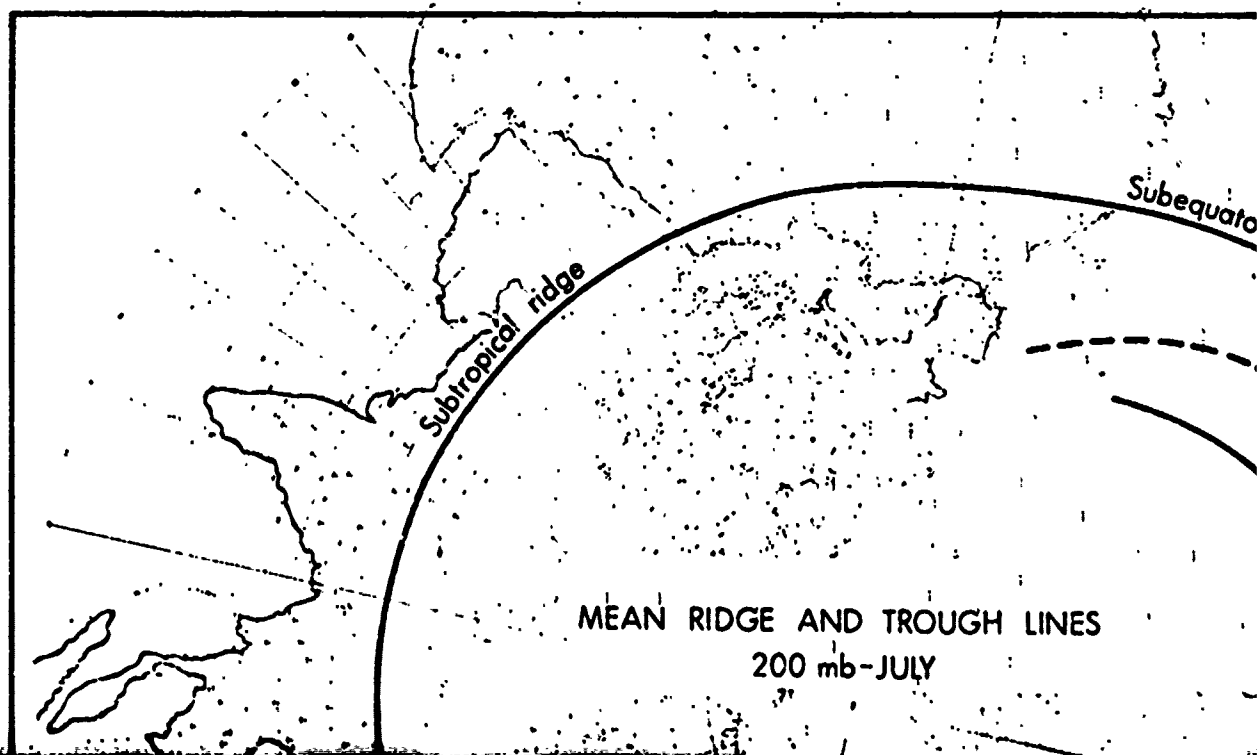
3.1 Systems

Since flow patterns are rather complex during the Northern Hemisphere summer, discussion is aided if major circulation features

are labelled. In Figure 1, the trough and double ridges are referred to as the subtropical ridge and the poleward of the subtropical ridge of the North Atlantic. The subequatorial ridge of the North Atlantic, Africa, Asia, and the North

The trough between the subtropical ridge and the subequatorial ridge will, in general, be referred to as the Trough (TUTT). It is common to the central Pacific and Atlantic. The term "Trough" is used since similar troughs exist in the eastern North Pacific, on occasion for shorter periods extending westward from

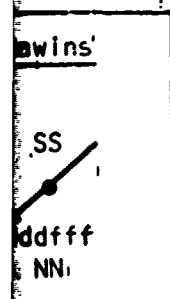
Another near-equatorial trough exists from the development and the sphere without a counterpart is depicted in Figure 3. It is from January to August. The equatorial region exists in either hemisphere. In the North Pacific between 10N and



are labelled. In Figure 2, the ridge system has a spiral configuration and double ridges exist over the oceans. When only a single ridge exists in a hemisphere or portions of a hemisphere, it will be referred to as the subtropical ridge. When a double ridge system exists, the equatorward ridge will be referred to as the subequatorial ridge and the poleward one as the subtropical ridge. Note that the subequatorial ridge of the western and central North Pacific becomes the subtropical ridge across the United States and the North Atlantic. The subequatorial ridge of the eastern North Pacific, northern South America and the North Atlantic becomes the subtropical ridge over Africa, Asia, and the North Pacific.

The trough between the subequatorial and subtropical ridge will, in general, be referred to as the Tropical Upper-Tropospheric Trough (TUTT). It is commonly called the Mid-Pacific Trough (MPT) in the central Pacific and the Mid-Atlantic Trough (MAT) in the central Atlantic. The term "Tropical Upper-Tropospheric Trough" is preferred since similar troughs exist during summer in the Southern Hemisphere, eastern North Pacific, Central America, and the Gulf of Mexico. On occasion for shorter periods it is observed as a continuous feature extending westward from the Mediterranean Sea to Asia (Sadler, 1963).

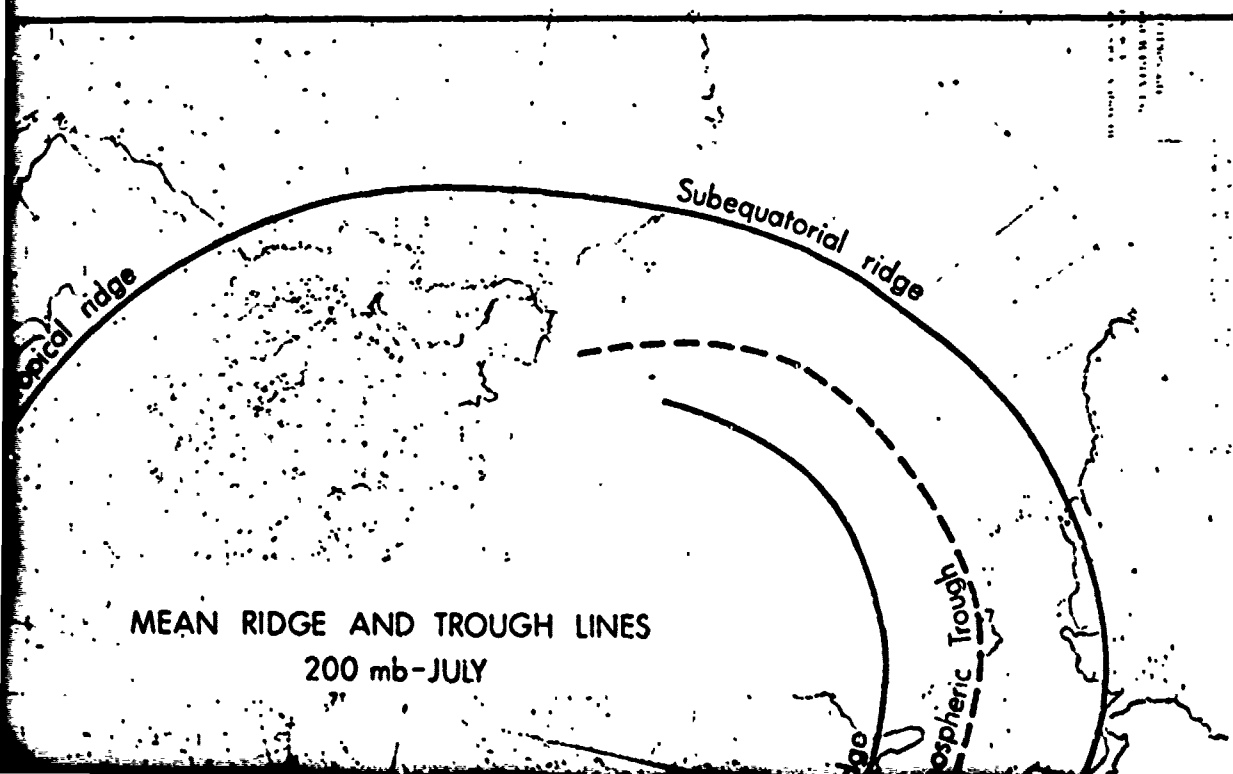
Another near-equatorial system which needs defining results from the development and existence of a dynamic system in one hemisphere without a counterpart in the opposite hemisphere. The evolution is depicted in Figure 3 by sketches of the changing 200-mb features from January to August. In January [Figure 3(a)], westerly flow covers the equatorial region east of 170W in the absence of a ridge system in either hemisphere. In May, a ridge forms over the eastern North Pacific between 10N and 15N, and by June [Figure 3(b)], it extends



component

ts (flag = 50
rt barb = 5 knots)

ex during the Northern
circulation features



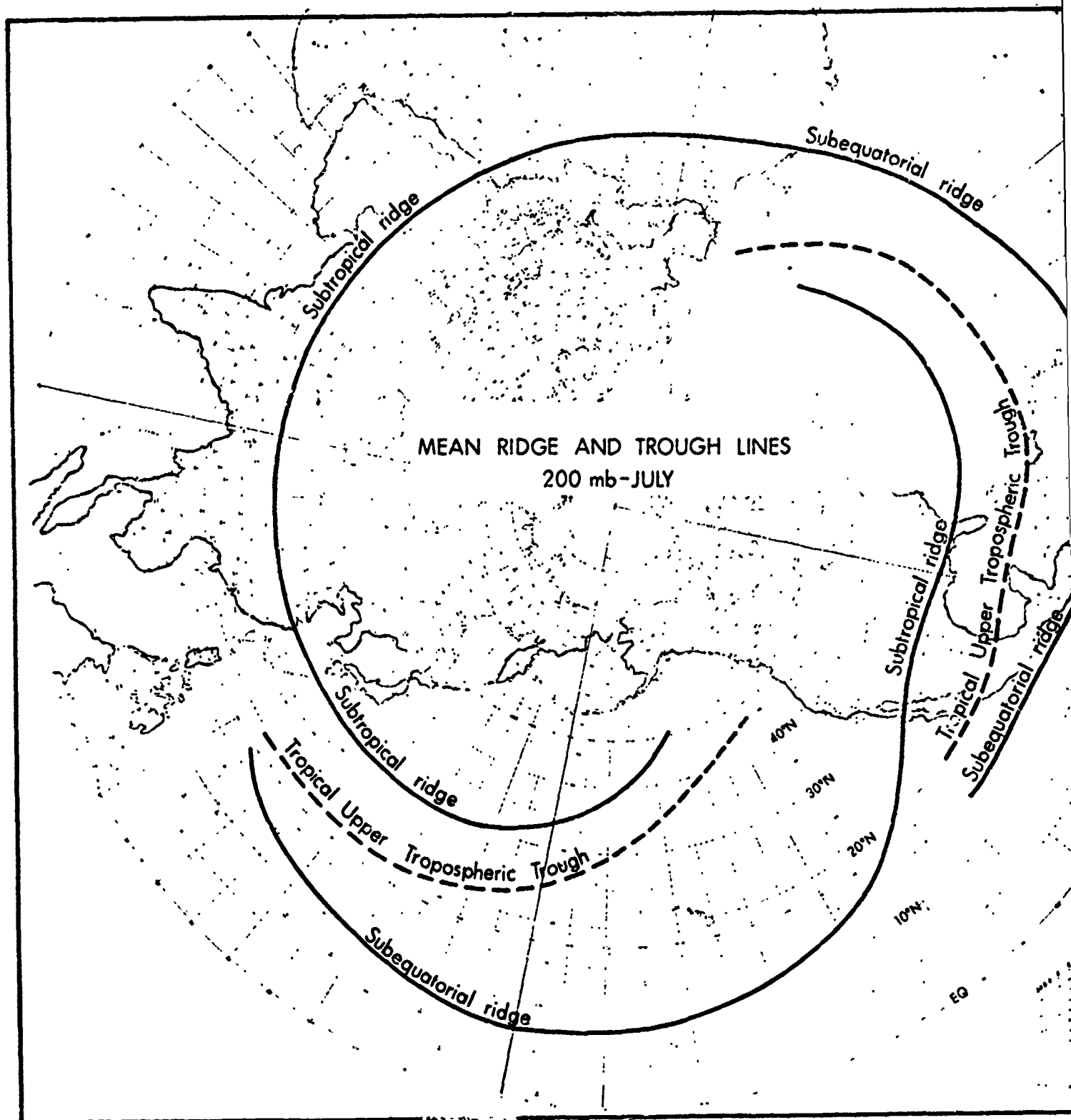
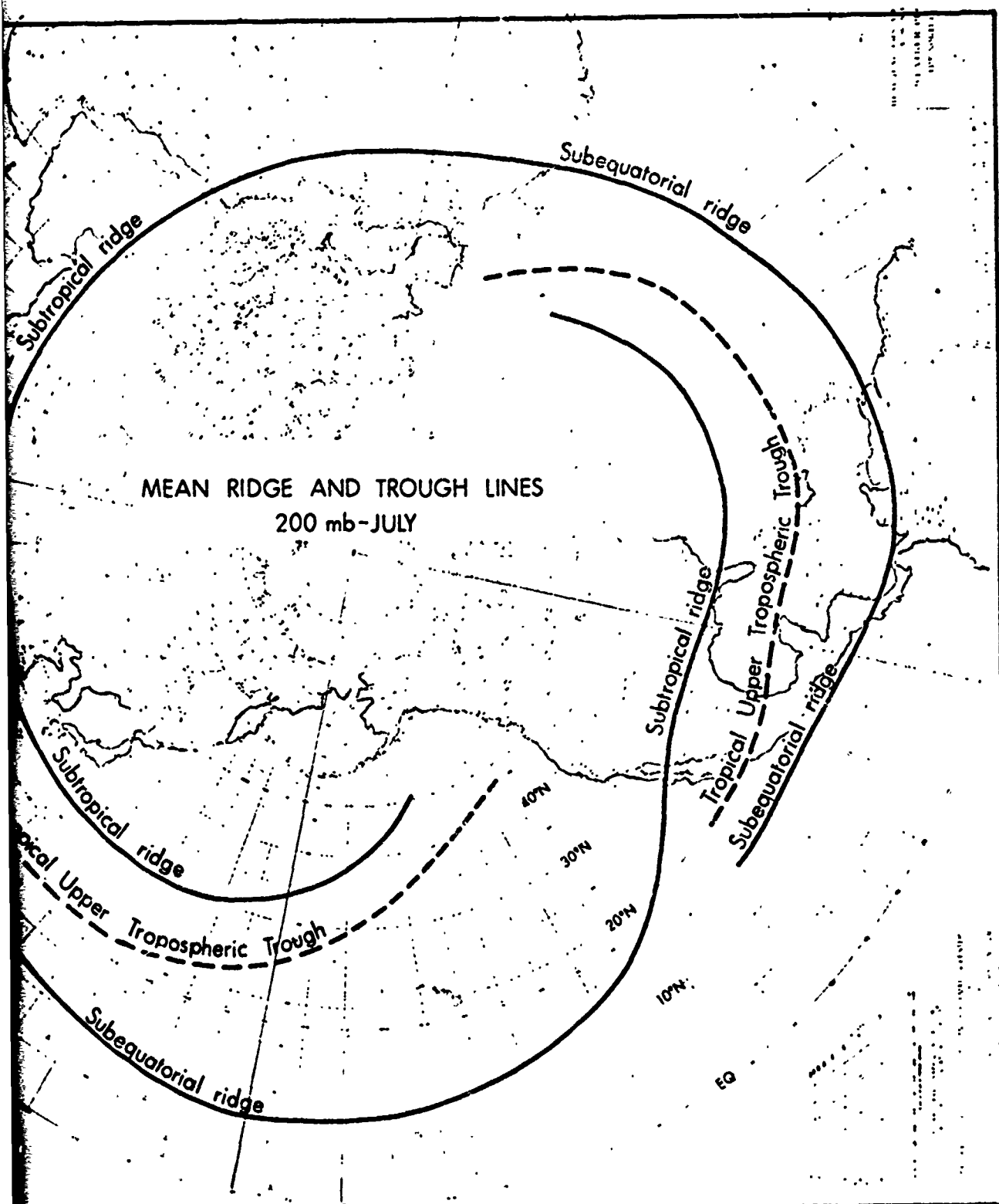
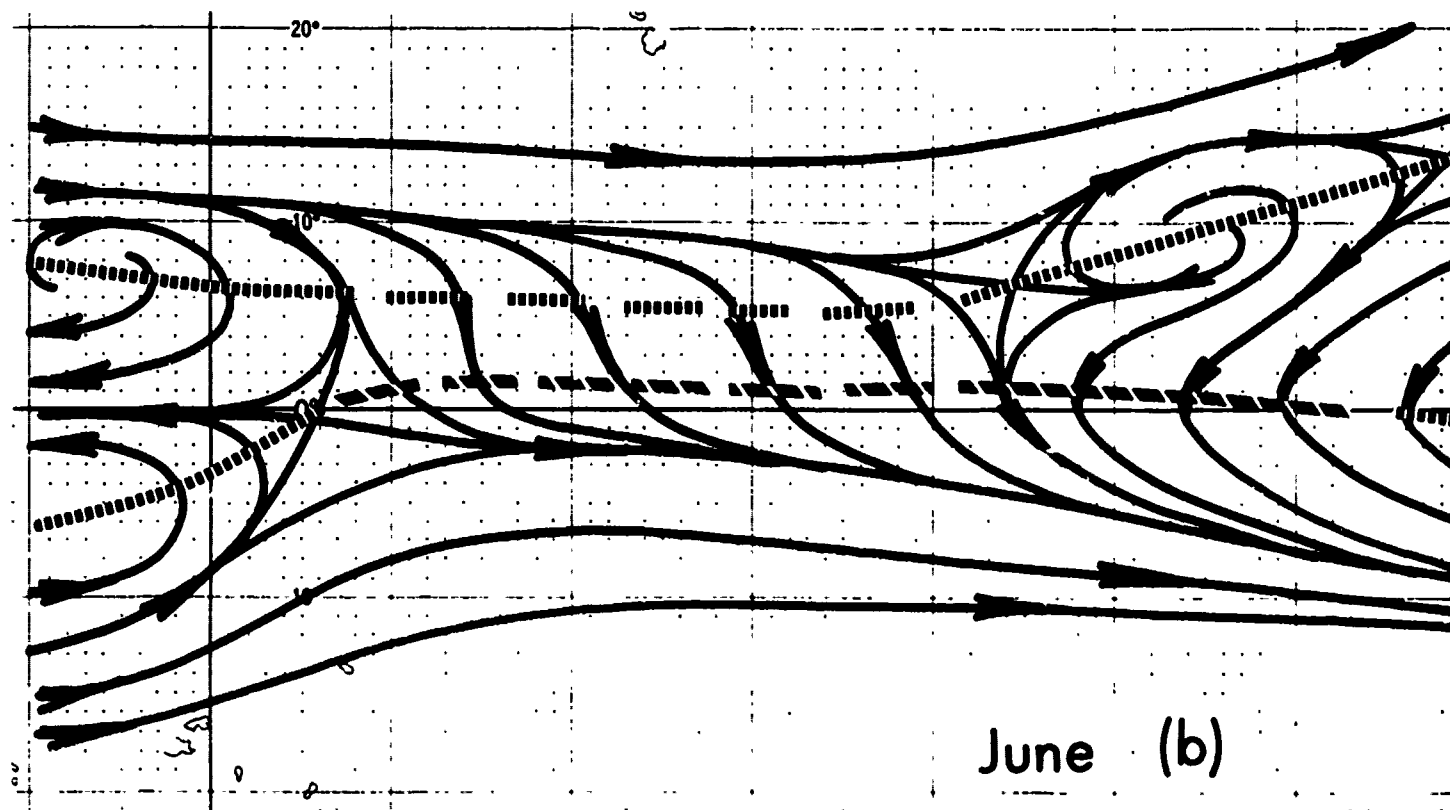
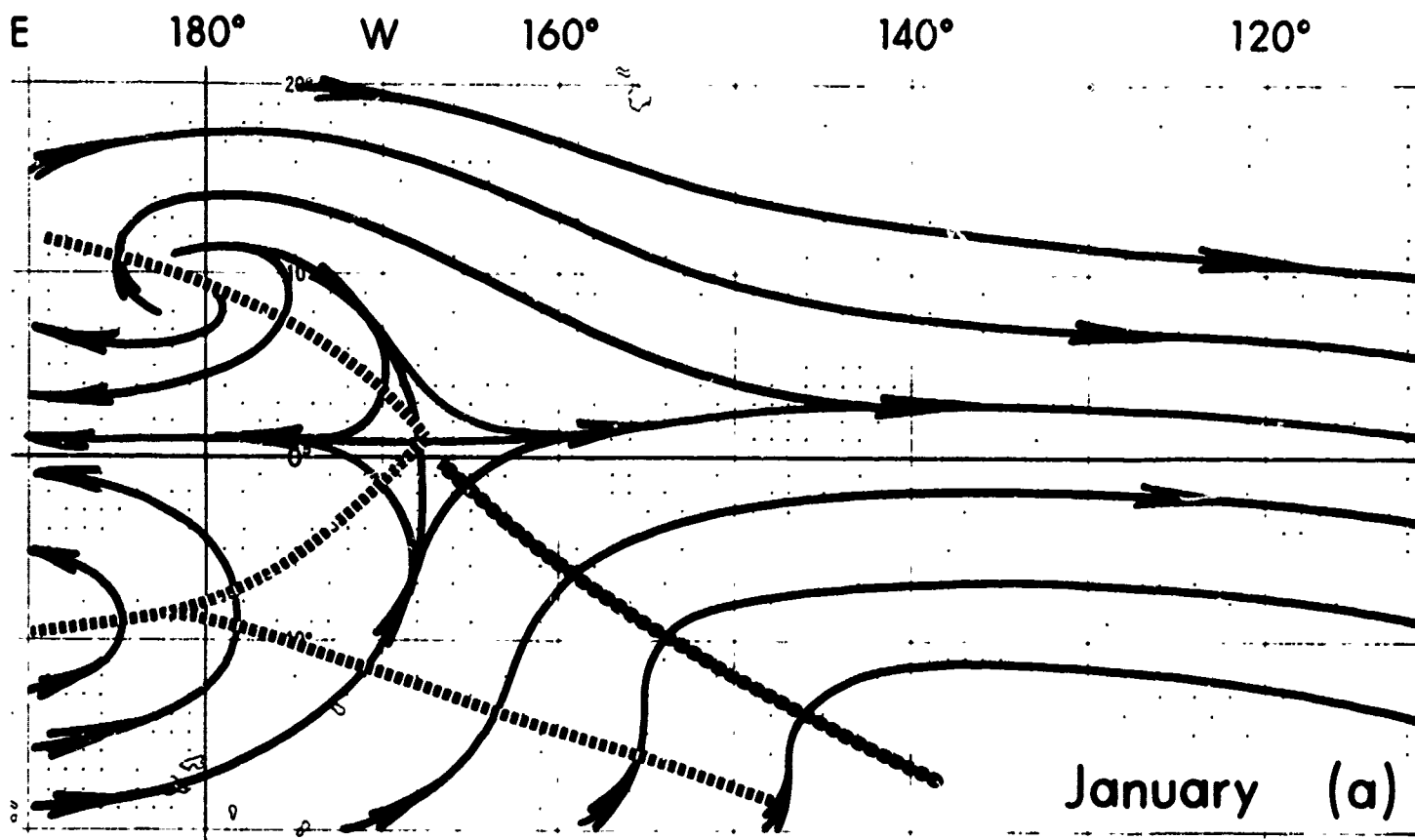


Figure 2. Mean July positions of ridges and troughs at 200 mb.



ons of ridges and troughs at 200 mb.



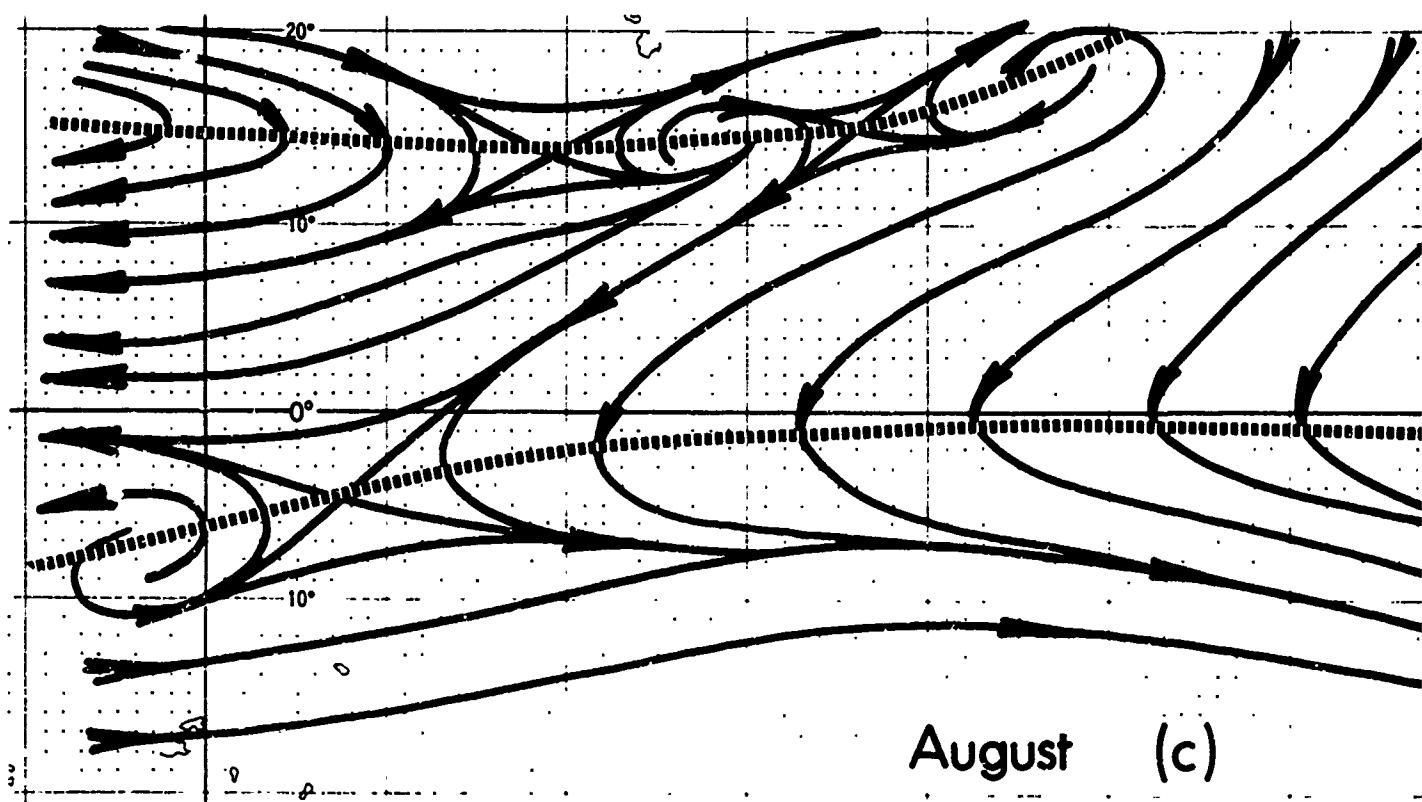
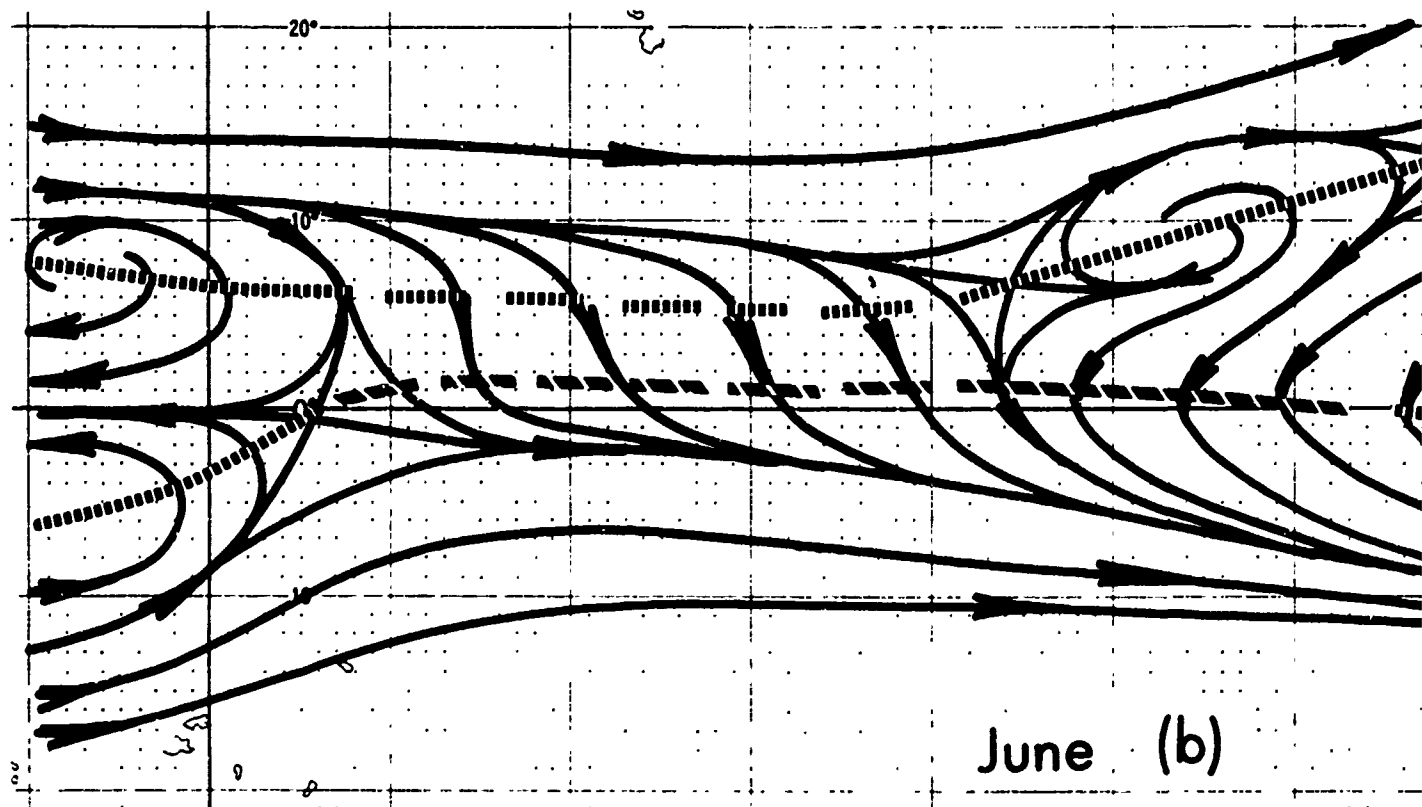
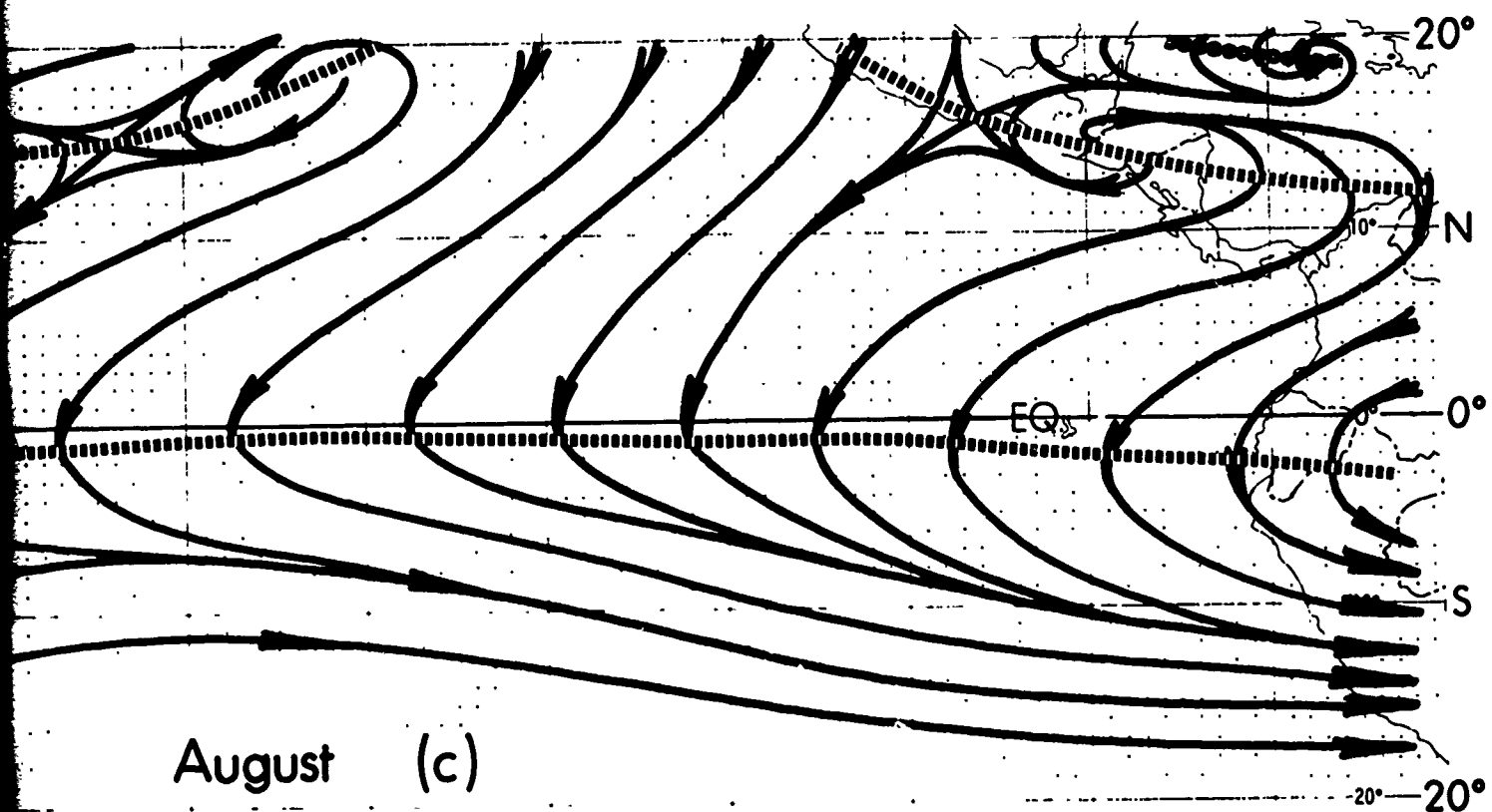
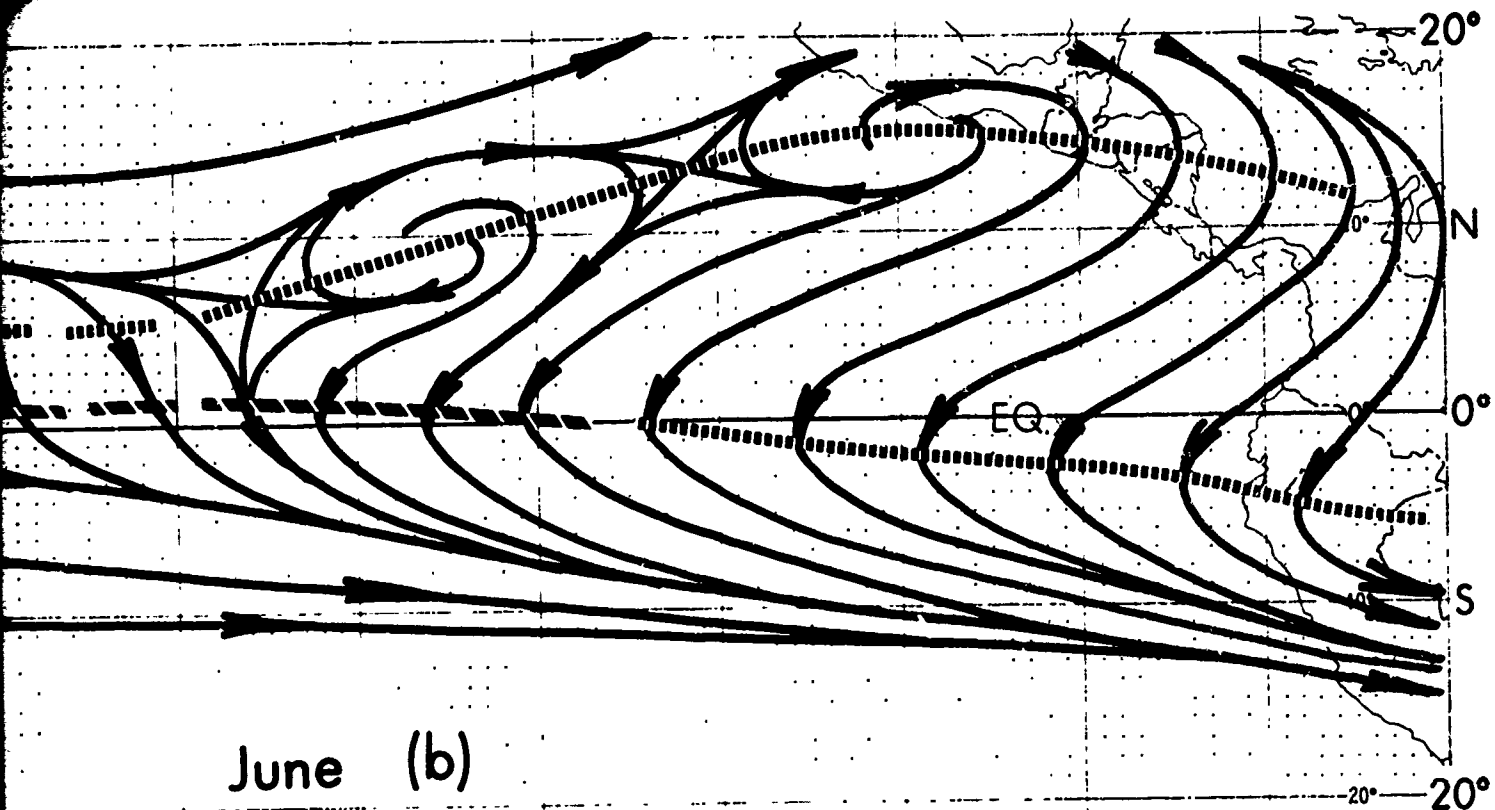


Figure 3. Schematic of 200 mb ridge development in the Northern Hemisphere over the eastern P and the concurrent establishment of a buffer system in an equatorial region.



in the Northern Hemisphere over the eastern Pacific
 buffer system in an equatorial region.

westward to near 140W. Easterly winds are established south of the ridge line. No counterpart ridge forms in the Southern Hemisphere and westerlies exist from the equator southward. A counterclockwise turning wind system is therefore established between the westerlies of the Southern Hemisphere and the easterly flow south of the ridge line. The ridge continues to strengthen and move northward, and by August [figure 3(c)], mean easterly flow is established across the North Pacific south of the ridge line. The axis of the counterclockwise system between the easterlies and the Southern Hemisphere westerlies lies very near the equator. This axis can move back and forth across the equator and even slope with height across the equator (see July and September plates). The sense of rotation is cyclonic when north of the equator and anticyclonic when south of the equator. Similar circulation systems in the lower troposphere over the western Pacific and Indian Ocean have been referred to as buffer systems (Sadler and Harris, 1970), implying only a wind-turning zone between two independently driven wind systems of opposite directions. The same nomenclature of buffer system will be used herein.

3.2 Major Currents

(a) Westerlies. The westerly currents of the mid- or temperate latitudes are persistent features throughout the year and will be referred to as the temperate westerlies, or the temperate jets if the mean speeds exceed 80 kt.

The westerly currents of tropical latitude origin separated from the temperate westerlies will be referred to as the subtropical westerlies. These currents normally exist equatorward of the tropical upper-tropospheric troughs.

The westerly currents of the equatorial region appear to be a mix or extension of the temperate westerlies and/or the subtropical westerlies and will be referred to in these terms as appropriate.

(b) Easterlies. The upper-tropospheric troughs to as the tropical easterlies or near-equatorial regions of the hemispheres or between the equator and the subequatorial troughs to as the equatorial easterlies.

The maximum data used as an underlying mb charts to assure previous and following months back and forth with the

The quality of the smoothing was required winds and rawins. More speed, particularly with observations highly variable

The monthly discussion and their changes from discussion is 200 mb to

Differences between are minor. The major increase with altitude

6. ACKNOWLEDGEMENTS

Appreciation is expressed to Mr. Louis Oda for plotting and drafting the figures and to Mrs. S. Arita for typing the manuscript.

established south of the Southern Hemisphere ridge. A counterclockwise flow between the westerlies of the Southern Hemisphere south of the ridge line. Equatorward, and by August the flow is reversed across the North Pacific. The counterclockwise flow in the Southern Hemisphere westerlies is reversed back and forth across the equator (see July and August). This is cyclonic when north of the equator. Similar systems exist over the western Pacific for the Northern Hemisphere systems (Sadler and others). The same nomen-

climates of the mid- or temperate zone throughout the year and will be referred to as the temperate jets if

of latitude origin are referred to as the latitude jets if they exist equatorward of

equatorial region appear to be similar and/or the subtropical terms as appropriate.

(b) Easterlies. The easterly current between the tropical upper-tropospheric trough and the subtropical ridge will be referred to as the tropical easterlies. The easterly current of the equatorial or near-equatorial region between the subtropical ridges of the two hemispheres or between the subtropical ridge of the Southern Hemisphere and the subequatorial ridge of the Northern Hemisphere will be referred to as the equatorial easterlies.

4. ANALYSIS

The maximum data composite PIREP chart was analyzed first and used as an underlying control for analyses of the 300-, 250-, and 200-mb charts to assure vertical consistency. The analyses for the previous and following months were also used as underlays, and adjustments back and forth were made to assure time continuity.

The quality of the PIREP data was remarkably good. Very little smoothing was required in the streamline analyses to mesh the PIREP winds and rawins. More smoothing was necessary in analyzing the wind speed, particularly where data were sparse and the number of aircraft observations highly variable.

5. PLATE DISCUSSION

The monthly discussions dwell on the major circulation systems, and their changes from the previous month. The reference level for discussion is 200 mb unless noted otherwise.

Differences between the circulation patterns at the three levels are minor. The major differences are in wind speeds which generally increase with altitude.

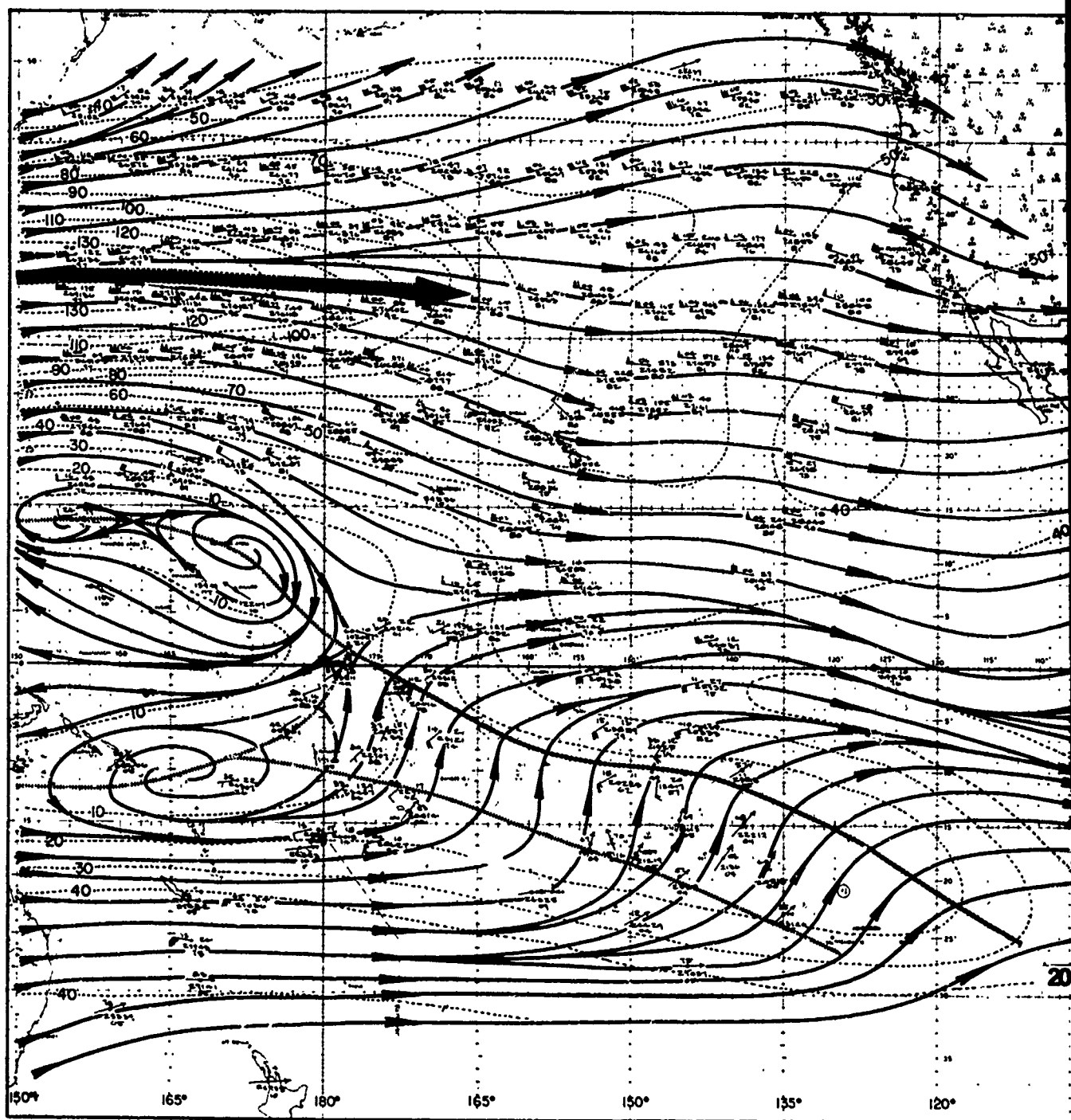
6. ACKNOWLEDGEMENTS

Appreciation is expressed to Mr. Louis Oda for plotting and drawing the figures and to Mrs. S. Arita for typing the manuscript.

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- Sadler, J. C. and B. E. Harris, 1970: The mean tropospheric circulation and cloudiness over Southeast Asia and neighboring areas. Hawaii Institute of Geophysics, Scientific Report No. 1, AFCRL-70-0489 and HIG-70-26, University of Hawaii, 37 pp.

Note: For those who may make frequent use of the charts it is suggested that the speed fields be color-shaded for ease in determining the position and intensity of the major wind systems.



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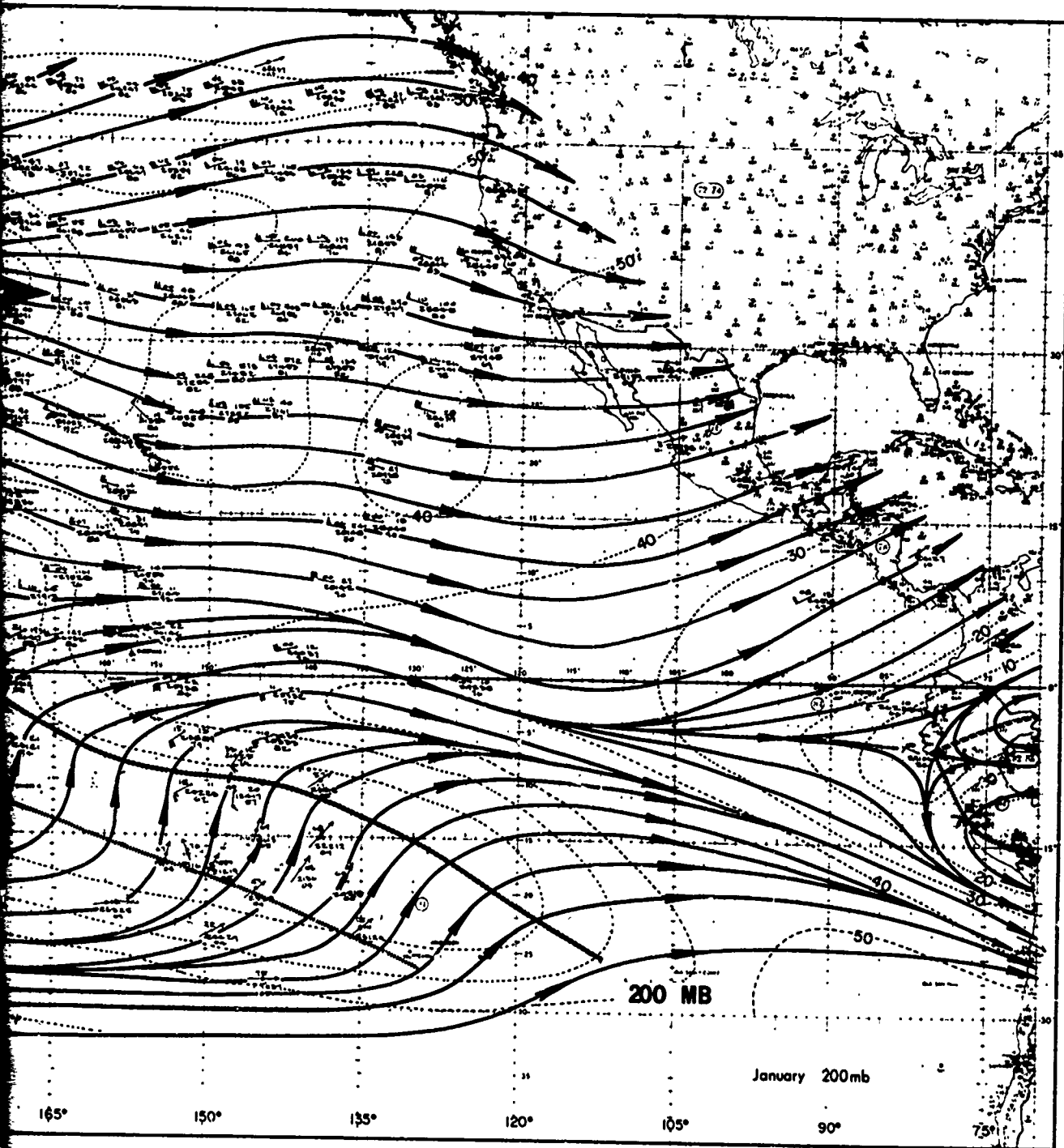
Northern Hemisphere

A steady, persistent temperate jet stream with a core speed of near 135 kt enters the area along 35N. Speed decreases rather rapidly eastward, and there is a "fanning" in direction downstream from the core center with an apparent splitting into two branches. The northernmost branch enters the United States near 46N as an anticyclonic turning current of near 50 kt maximum speed. The southern branch passes just north of Hawaii and enters the American coast over Baja

Southern Hemisphere

The subtropical ridge the equatorward branch the northern hemisphere subtropical ridge turning east-southeast some tropical upper tropospheric

The core of temperate



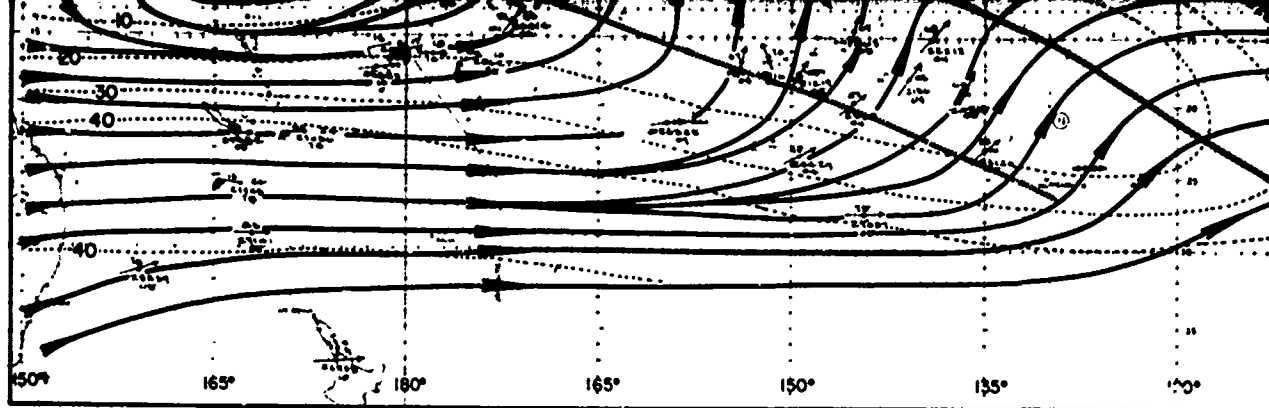
JANUARY

Southern Hemisphere

with a core speed of decreases rather rapidly downstream from the branches. The north- as an anticyclonic the southern branch can coast over Baja

The subtropical ridge, near 12S at 155E, branches near 170E with the equatorward branch terminating near 177W at the juncture with the northern hemisphere subtropical ridge and the poleward branch extending east-southeast some 10 degrees south of and paralleling the tropical upper tropospheric trough (TUTT).

The core of temperate westerlies with a maximum speed of approx-



JANUARY

Northern Hemisphere

A steady, persistent temperate jet stream with a core speed of near 135 kt enters the area along 35N. Speed decreases rather rapidly eastward, and there is a "fanning" in direction downstream from the core center with an apparent splitting into two branches. The northernmost branch enters the United States near 46N as an anticyclonic turning current of near 50 kt maximum speed. The southern branch passes just north of Hawaii and enters the American coast over Baja California as a cyclonic turning current. The maximum speed decreases to less than 50 kt east of Hawaii and increases again to 50 kt on the west coast. Between the two branches there is an area of minimum speed over the eastern Pacific.

Note that no winds with an easterly component are observed in the high steadiness (95 + %) region of the temperate jet west of 165W. This indicates that no deep westerly troughs with cut-off lows occur in this region as opposed to the eastern North Pacific which is a region of cut-off lows and blocking highs with omega patterns.

The subtropical ridge, near 14N at 155E, terminates near 177W, and westerly flow covers the tropical region eastward of 177W through Central America and northwestern South America.

Southern Hemisphere


The subtropical ridge in the southern hemisphere is located further east-southeast than in the northern hemisphere. The core of the ridge is located near 177W eastward of the equatorial region.

The core of the ridge is located near 177W eastward of the equatorial region. The core of the ridge is located near 177W eastward of the equatorial region.

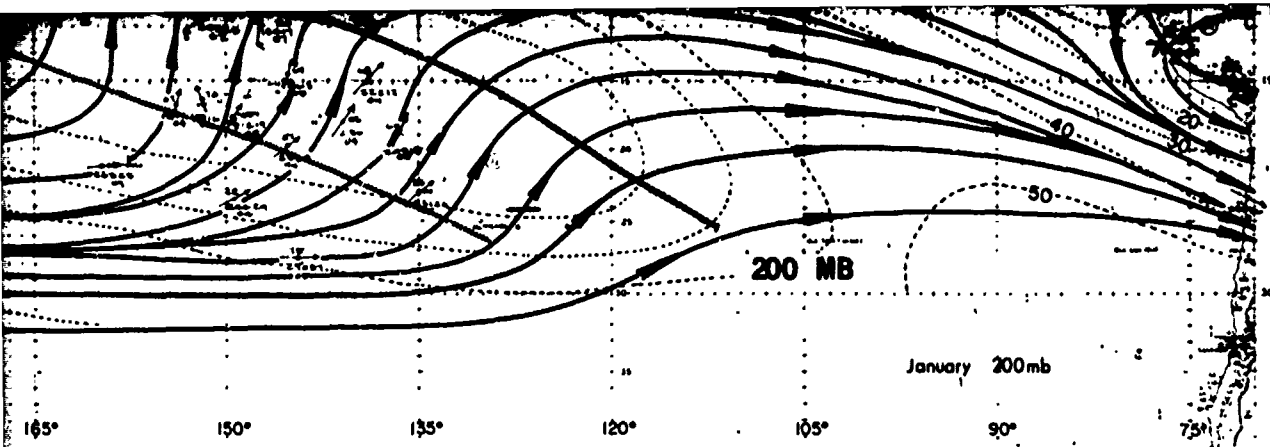
Equatorial Region

Equatorial easterly winds are observed in the two subtropical ridges near 177W eastward of the equatorial region.

PIREP Winds

EE nnnn

dddfff
SS

EE	-percentage of winds with an east component
nnnn	-number of observations
ddd	-mean resultant wind direction
fff	-mean resultant wind speed in knots (if 50 knots, long barb = 10 knots, short barb = 5 knots)
SS	-steadiness of winds in percent
NN	-number of years of record



JANUARY

Southern Hemisphere

With a core speed of increases rather rapidly downstream from the branches. The north- as an anticyclonic southern branch can coast over Baja maximum speed decreases again to 50 kt on the area of minimum

are observed in the jet west of 165W. In cut-off lows occur Pacific which is a mega patterns.

terminates near 177W, ward of 177W through

The subtropical ridge, near 12S at 155E, branches near 170E with the equatorward branch terminating near 177W at the juncture with the northern hemisphere subtropical ridge and the poleward branch extending east-southeast some 10 degrees south of and paralleling the tropical upper tropospheric trough (TUTT).


The core of temperate westerlies with a maximum speed of approximately 45 kt lies near 25S over eastern Australia. Speeds decrease eastward to the subtropical ridge--TUTT systems between 110W and 130W, and then increase to greater than 50 kt over western South America where the northwesterly stream of subtropical westerlies from the equatorial region merges with the temperate westerlies.

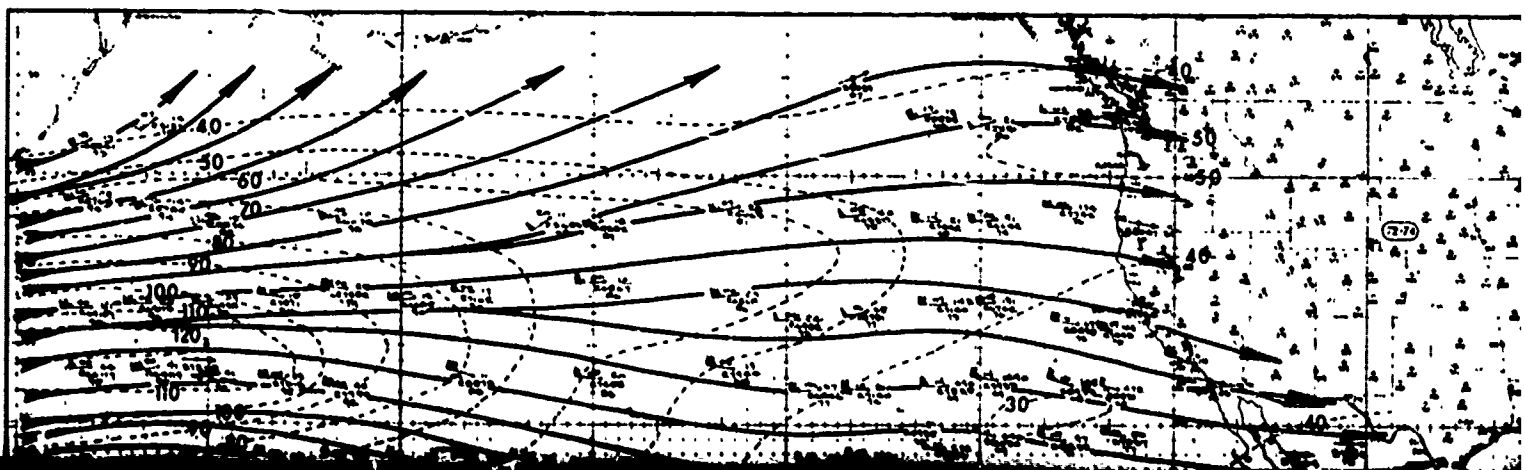
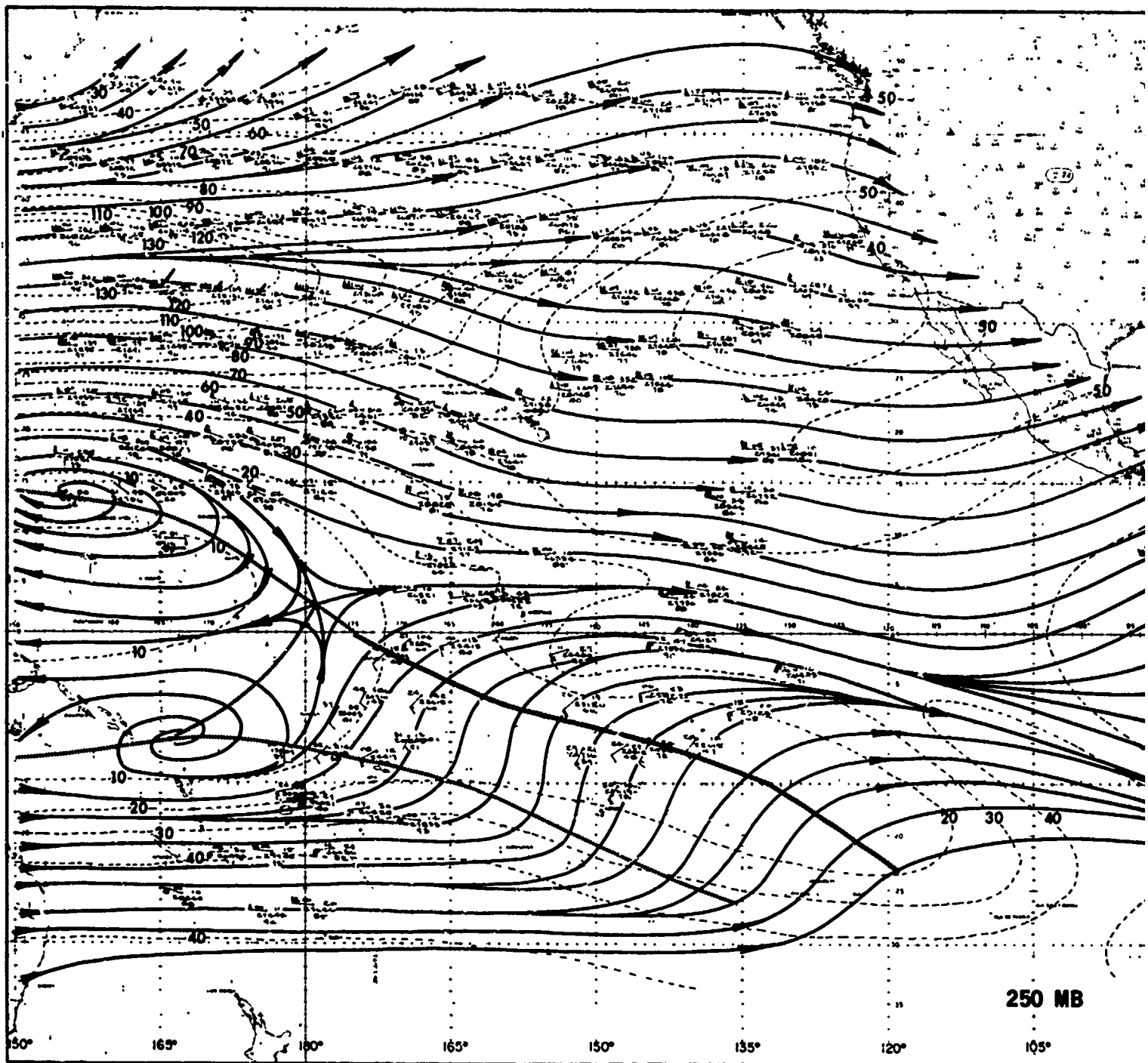
Equatorial Region

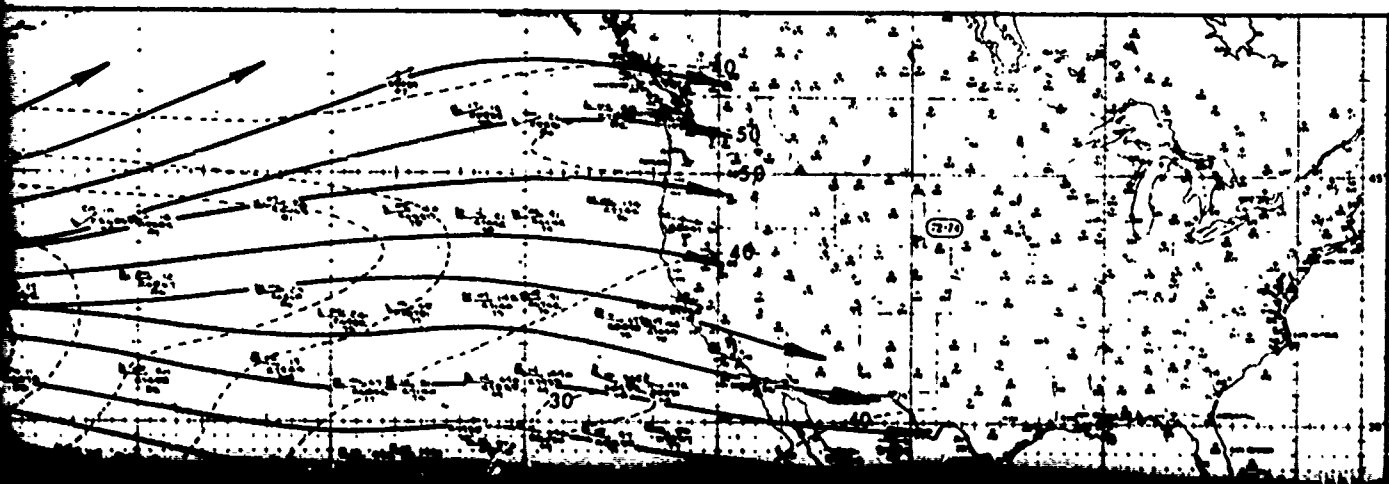
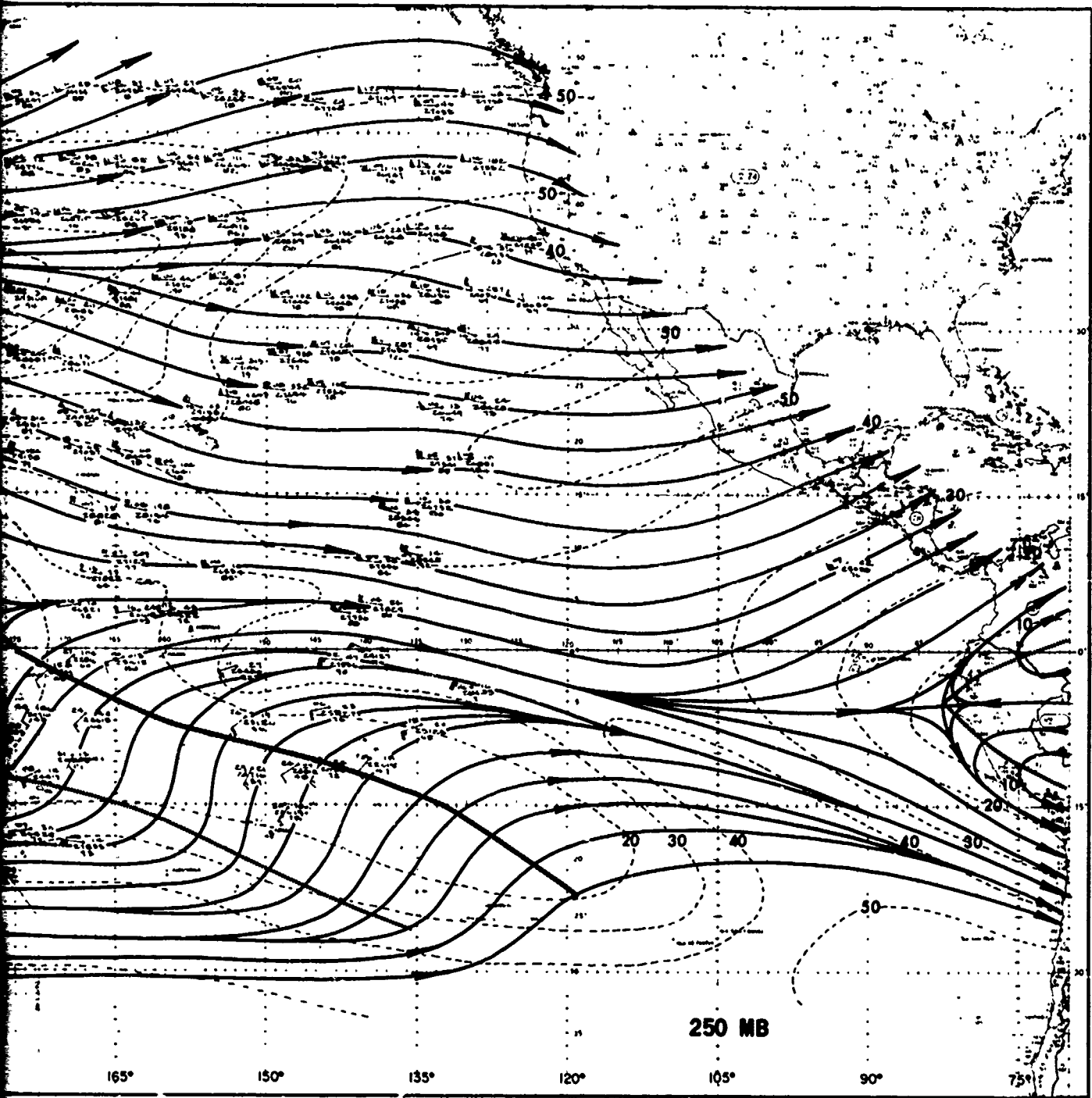
Equatorial easterlies exist from near 177W westward, between the two subtropical ridges. Westerlies cover the equatorial region from near 177W eastward to South America.

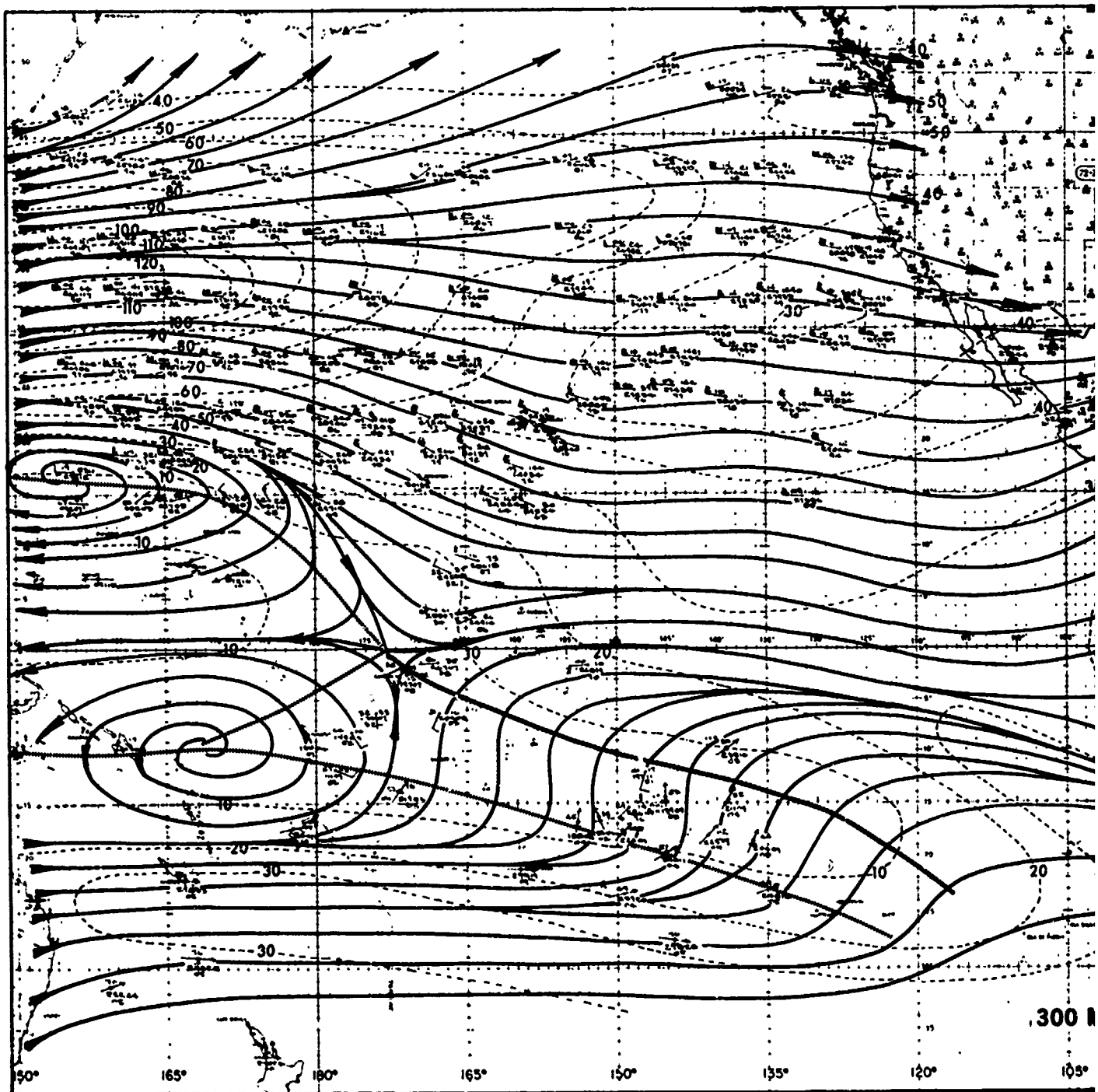
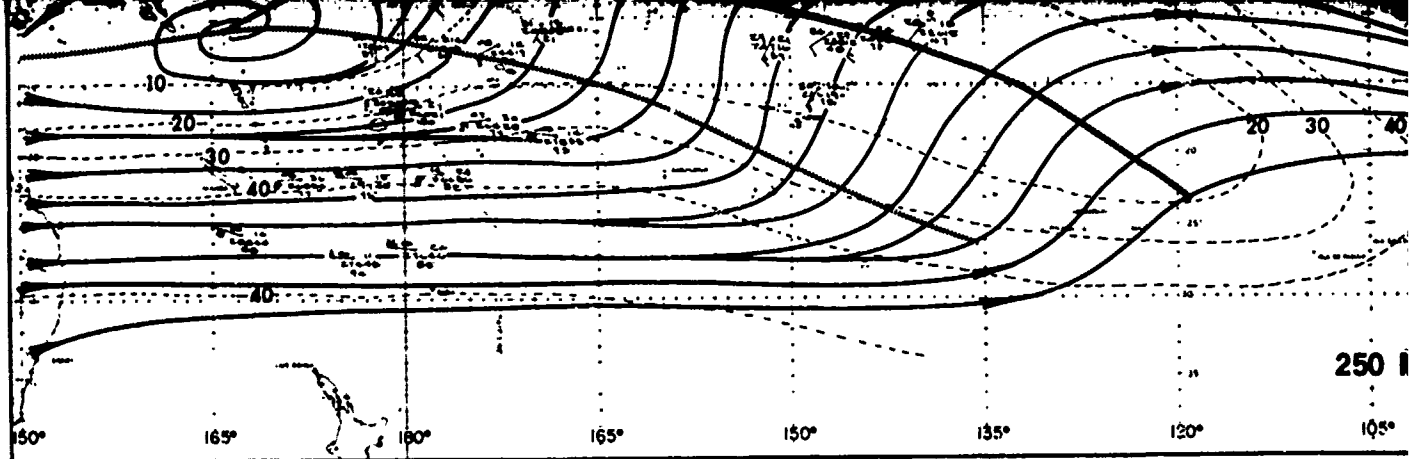
EE	-percentage of winds with an east component
nnnn	-number of observations
ddd	-mean resultant wind direction
fff	-mean resultant wind speed in knots (flag = 50 knots, long barb = 10 knots, short barb = 5 knots)
SS	-steadiness of winds in percent
NN	-number of years of record

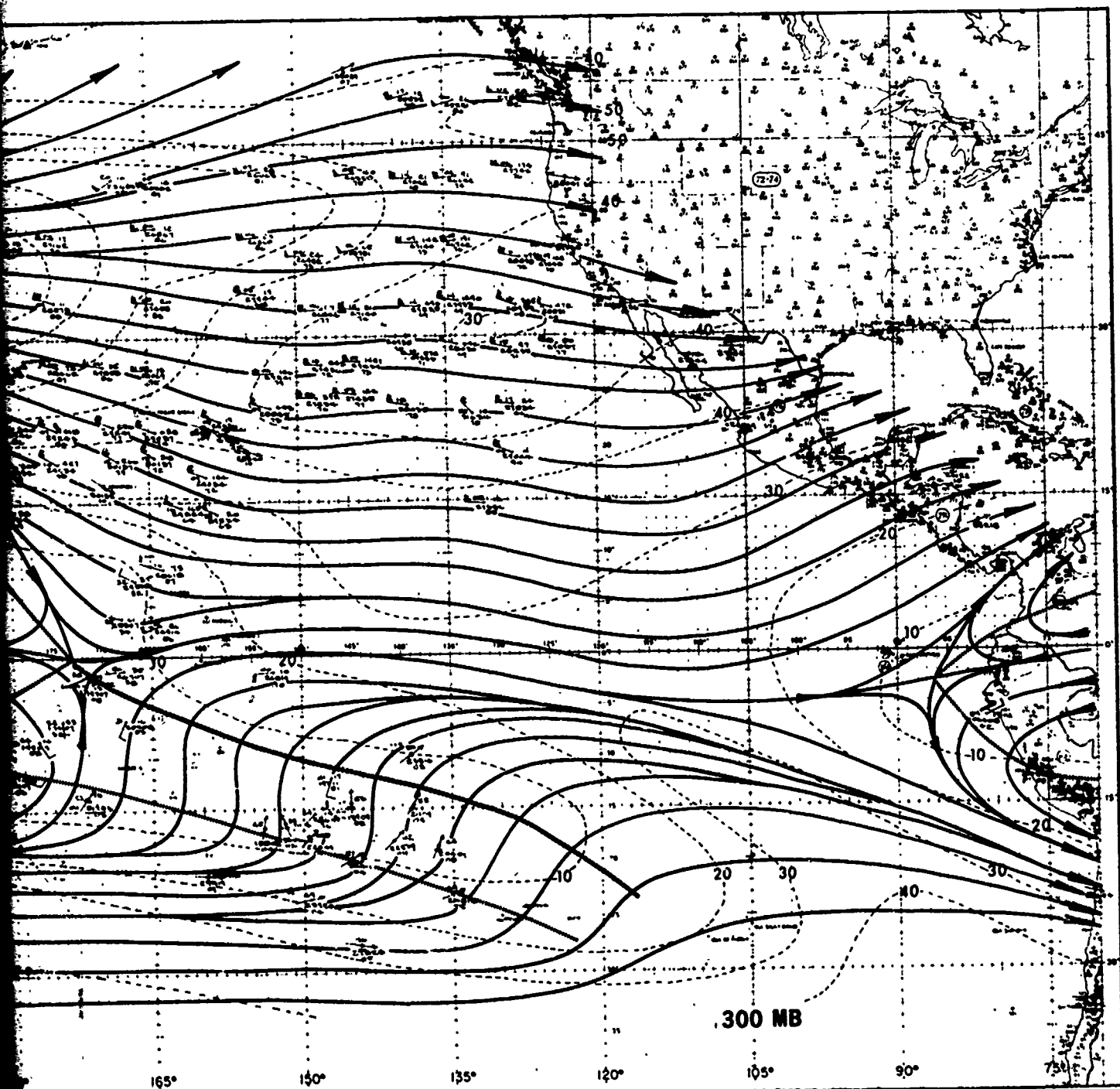
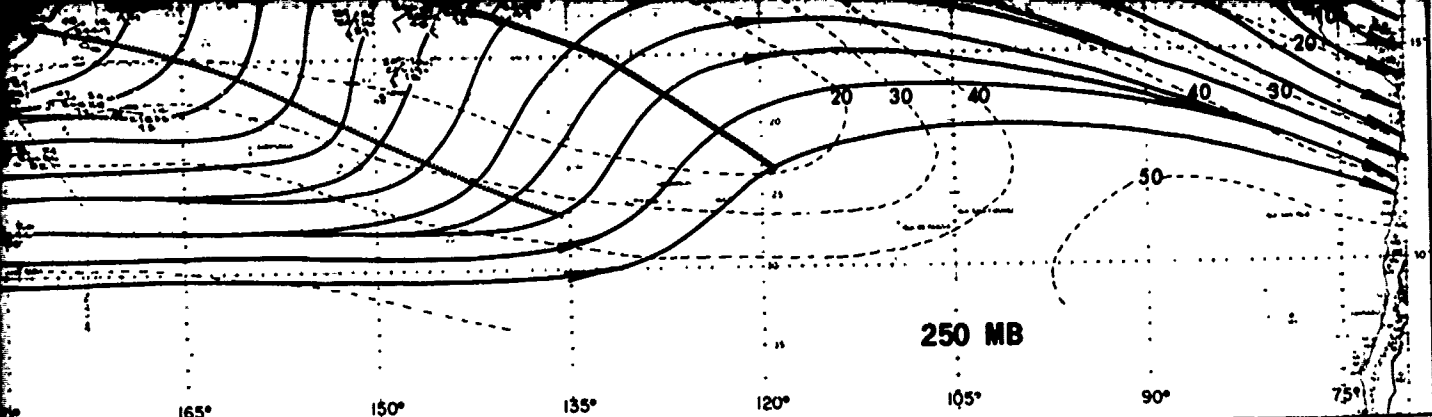
Rawins

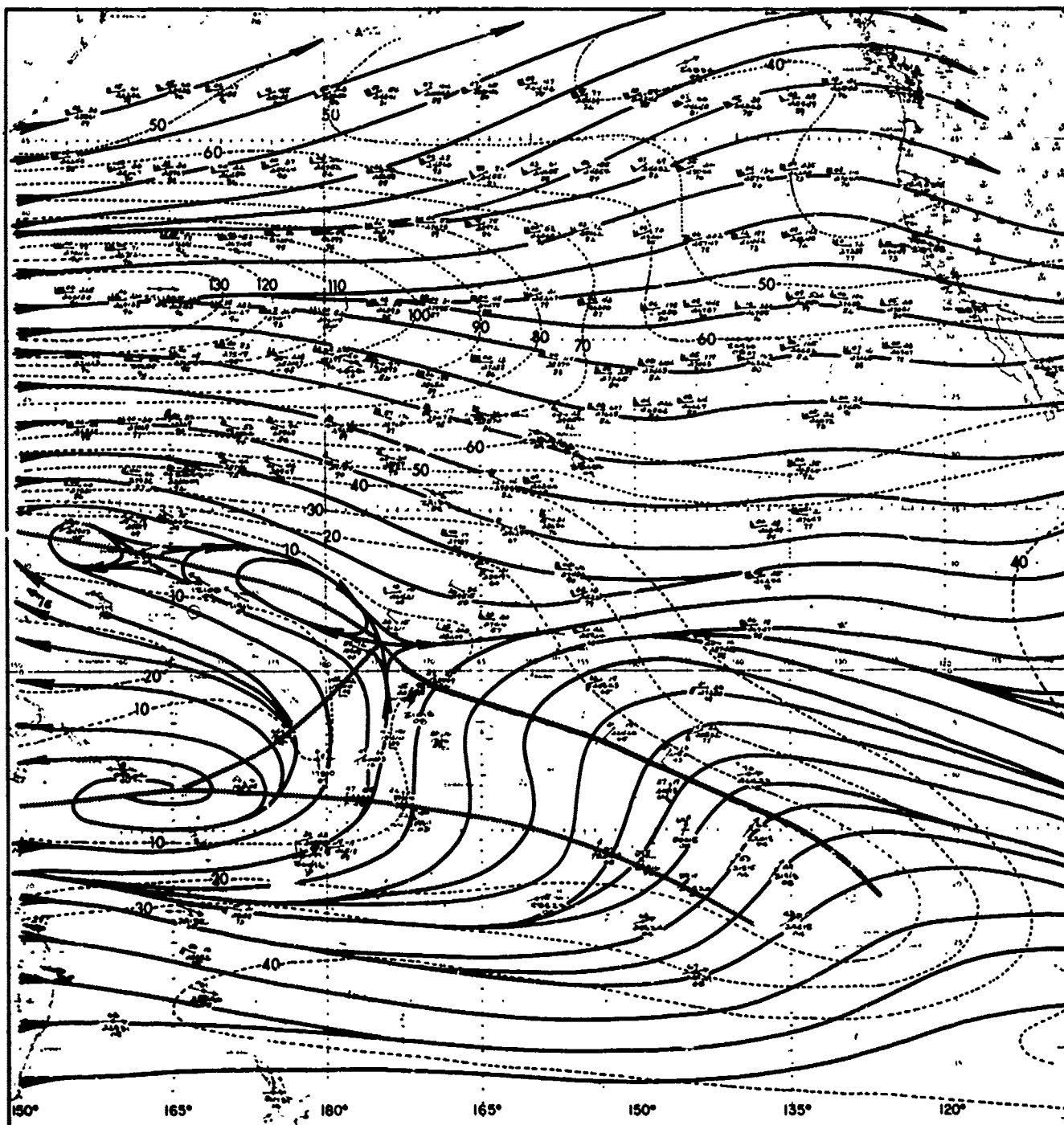
SS

 dddfff
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FEBRUARY

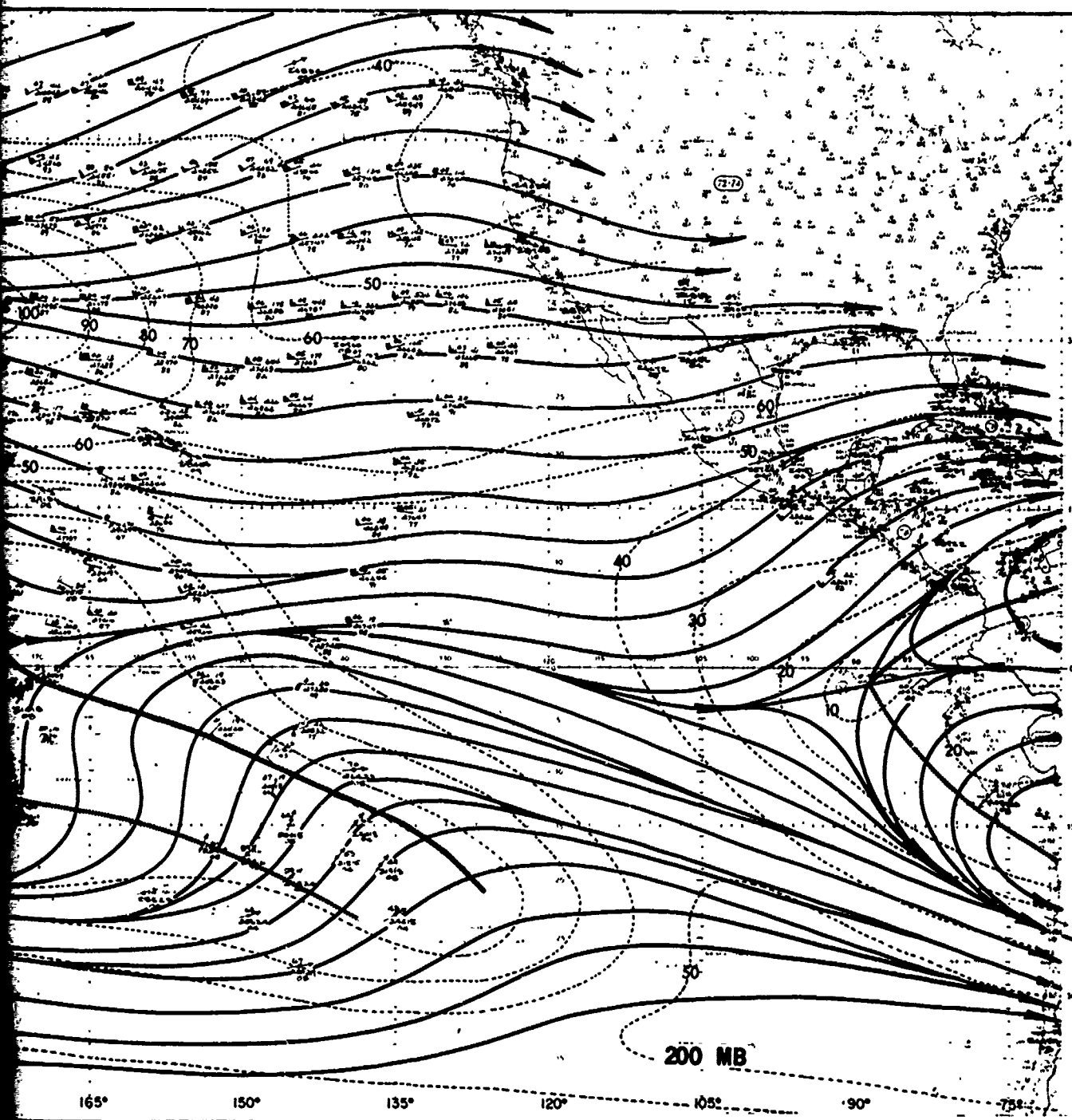
Northern Hemisphere

The temperate jet, with a core speed of near 135 kt, enters the area along 33N or slightly south of the January position. The downstream "fanning" of the direction field is very similar to January, but there is a definite change in the speed field. The southernmost branch is dominant with speeds of greater than 60 kt from just north of Hawaii through Baja California. The northernmost branch is not as prominent as in January, and the speeds are less than 40 kt off the

The temperate west slightly from January than 50 kt over western

The TUTT is a little more "active" as indicated by the French Polynesia

Equatorial Region



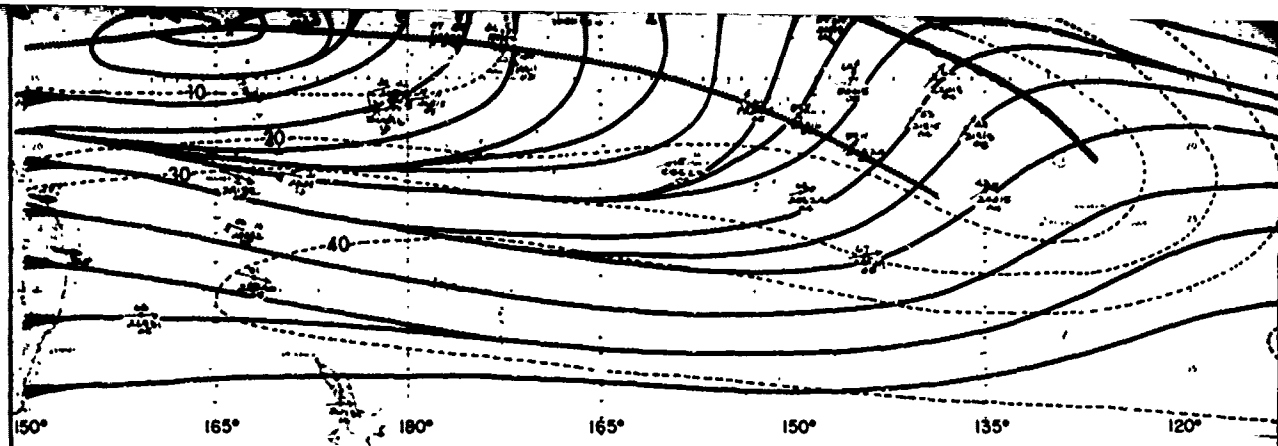
FEBRUARY

near 135 kt, enters the
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ary similar to January,
field. The southernmost
an 60 kt from just north
thernmost branch is not as
ss than 40 kt off the

The temperate westerlies over eastern Australia have decreased slightly from January to less than 40 kt. The speeds remain greater than 50 kt over western South America near 35S.

The TUTT is a little poleward of the January position and perhaps more "active" as indicated by the decrease in wind speeds and steadiness at the French Polynesian stations south of 14S.

Equatorial Region



FEBRUARY

Northern Hemisphere

The temperate jet, with a core speed of near 135 kt, enters the area along 33N or slightly south of the January position. The downstream "fanning" of the direction field is very similar to January, but there is a definite change in the speed field. The southernmost branch is dominant with speeds of greater than 60 kt from just north of Hawaii through Baja California. The northernmost branch is not as apparent as in January, and the speeds are less than 40 kt off the northwest coast of the United States.

The subtropical ridge is essentially unchanged from January.

Southern Hemisphere

The direction and the speed fields are quite similar to those of January.

The subtropical ridge is near the January position of 12S at 155E. Eastward of 155E it is slightly south of the January position.

The temperate jet, with a core speed of near 135 kt, enters the area along 33N or slightly south of the January position. The downstream "fanning" of the direction field is very similar to January, but there is a definite change in the speed field. The southernmost branch is dominant with speeds of greater than 60 kt from just north of Hawaii through Baja California. The northernmost branch is not as apparent as in January, and the speeds are less than 40 kt off the northwest coast of the United States.

The TUTT is a more "active" as in January at the French coast.

Equatorial Region

The boundary between the tropical and subtropical regions is near 175W, little changed from January.

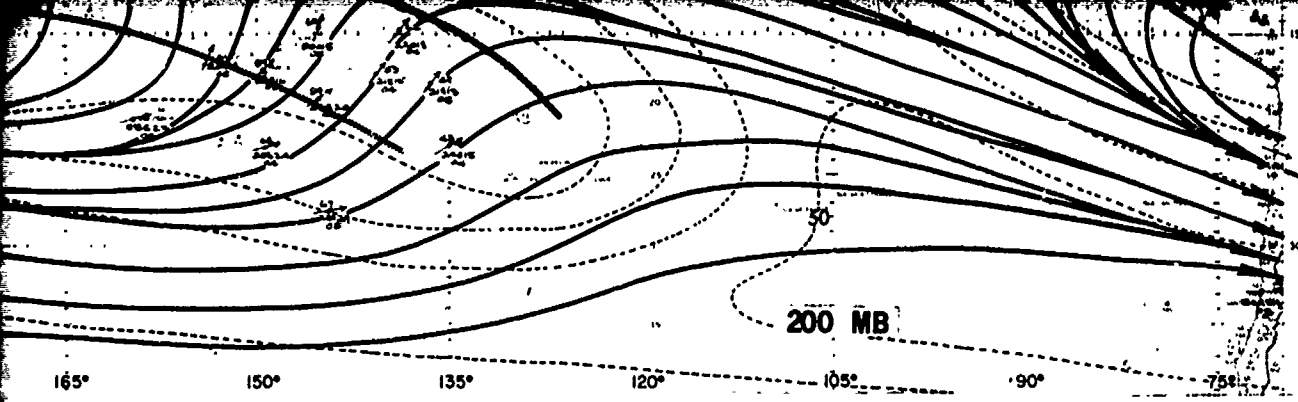
The anticyclonic circulation has expanded northward, with the center of action near 10S at 155E, as in January.

PIREP Winds

EE nnnn

dddfff
SS

EE	-percentage of winds with an east component
nnnn	-number of observations
ddd	-mean resultant wind direction
fff	-mean resultant wind speed in knots (if 50 knots, long barb = 10 knots, short barb = 5 knots)
SS	-steadiness of winds in percent
NN	-number of years of record



FEBRUARY

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 similar to January,
 field. The southernmost
 60 kt from just north
 northernmost branch is not as
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anged from January.

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The TUTT is a little poleward of the January position and perhaps more "active" as indicated by the decrease in wind speeds and steadiness at the French Polynesian stations south of 14S.


Equatorial Region

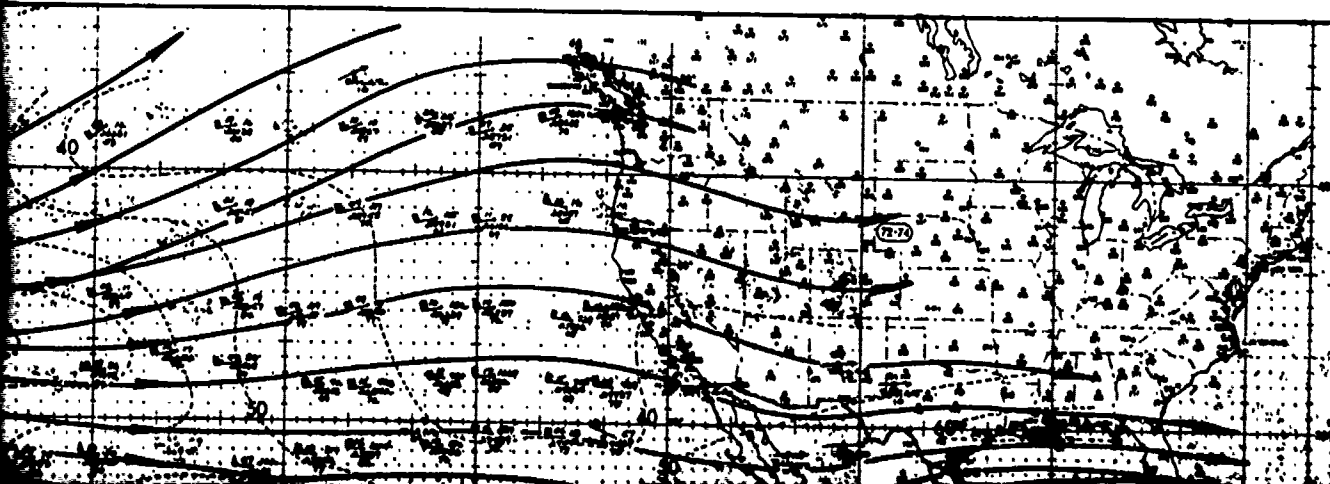
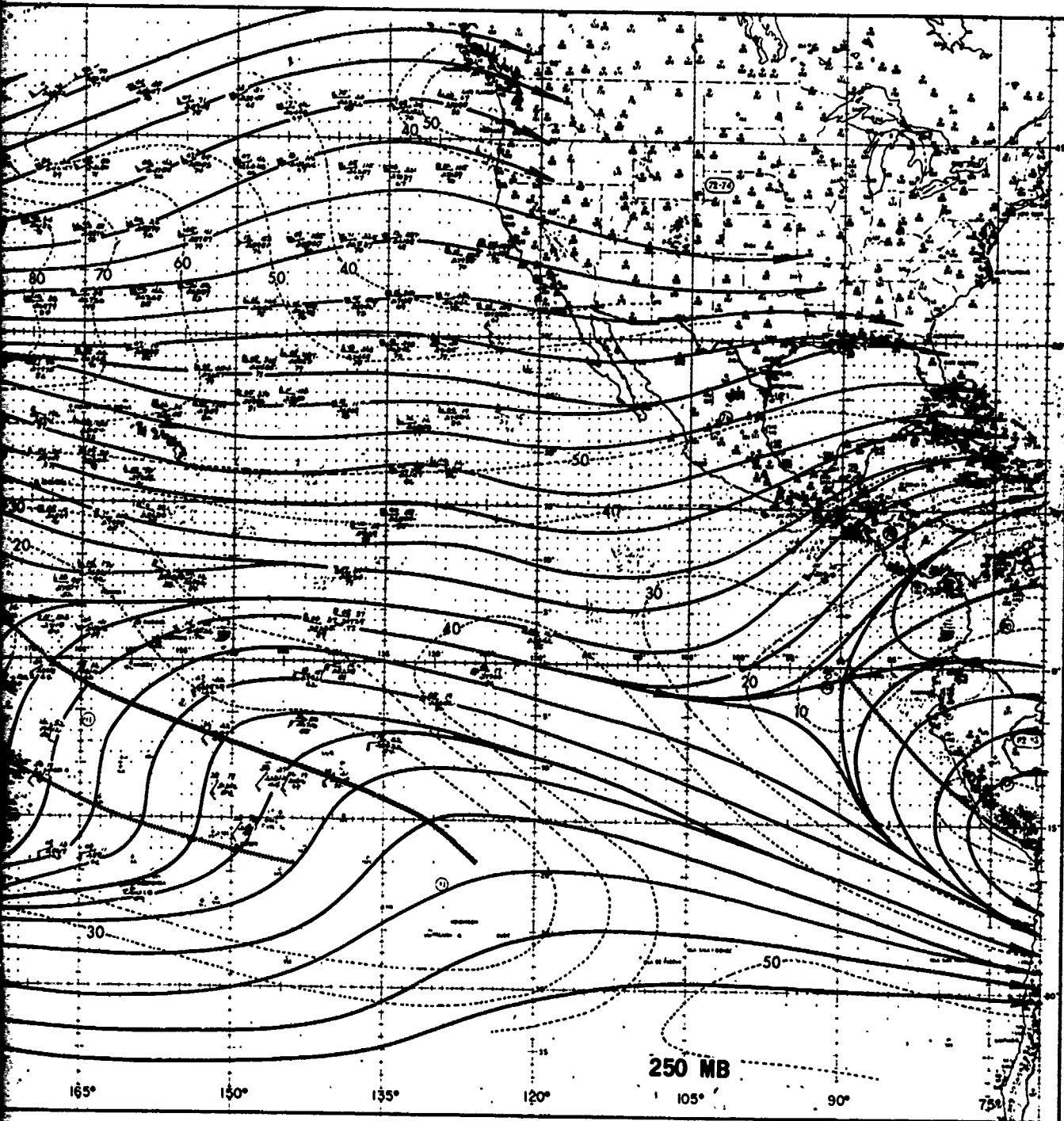
The boundary between equatorial easterlies to westerlies occurs near 175W, little different from January.

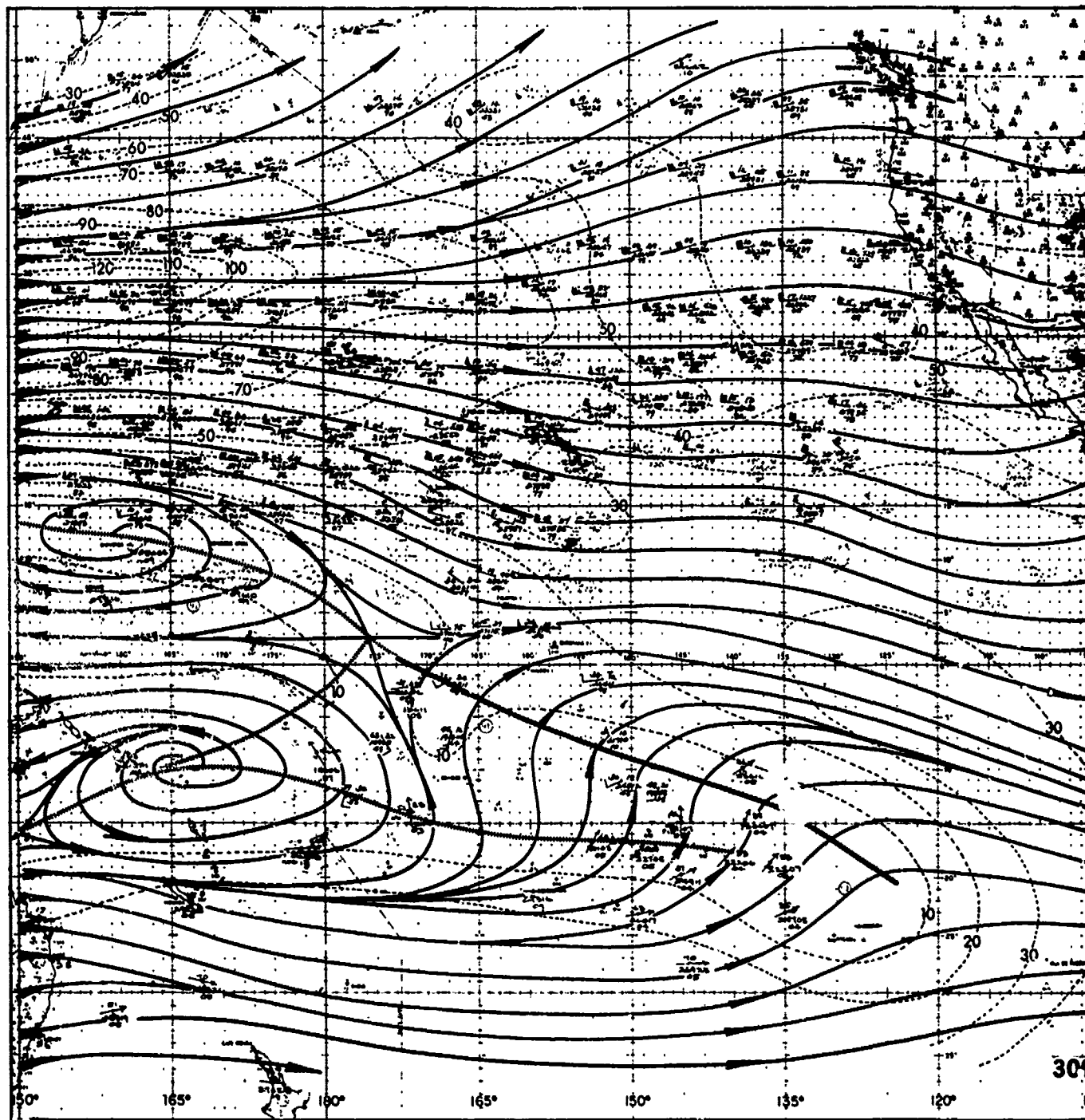
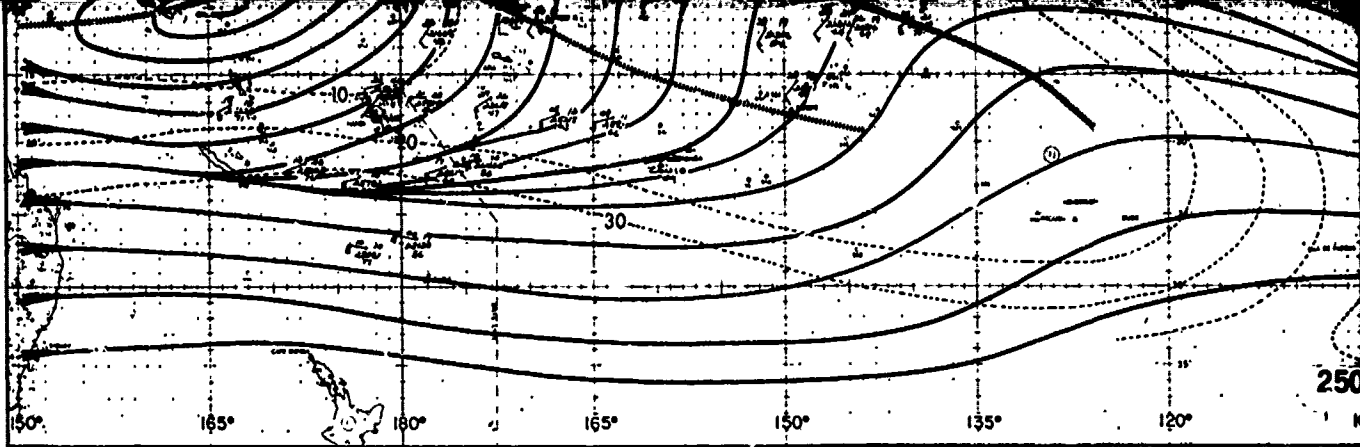
The anticyclonic cell south of the equator over South America has expanded northward, and equatorial easterlies have replaced the westerlies of January along the equator westward to near 85W.

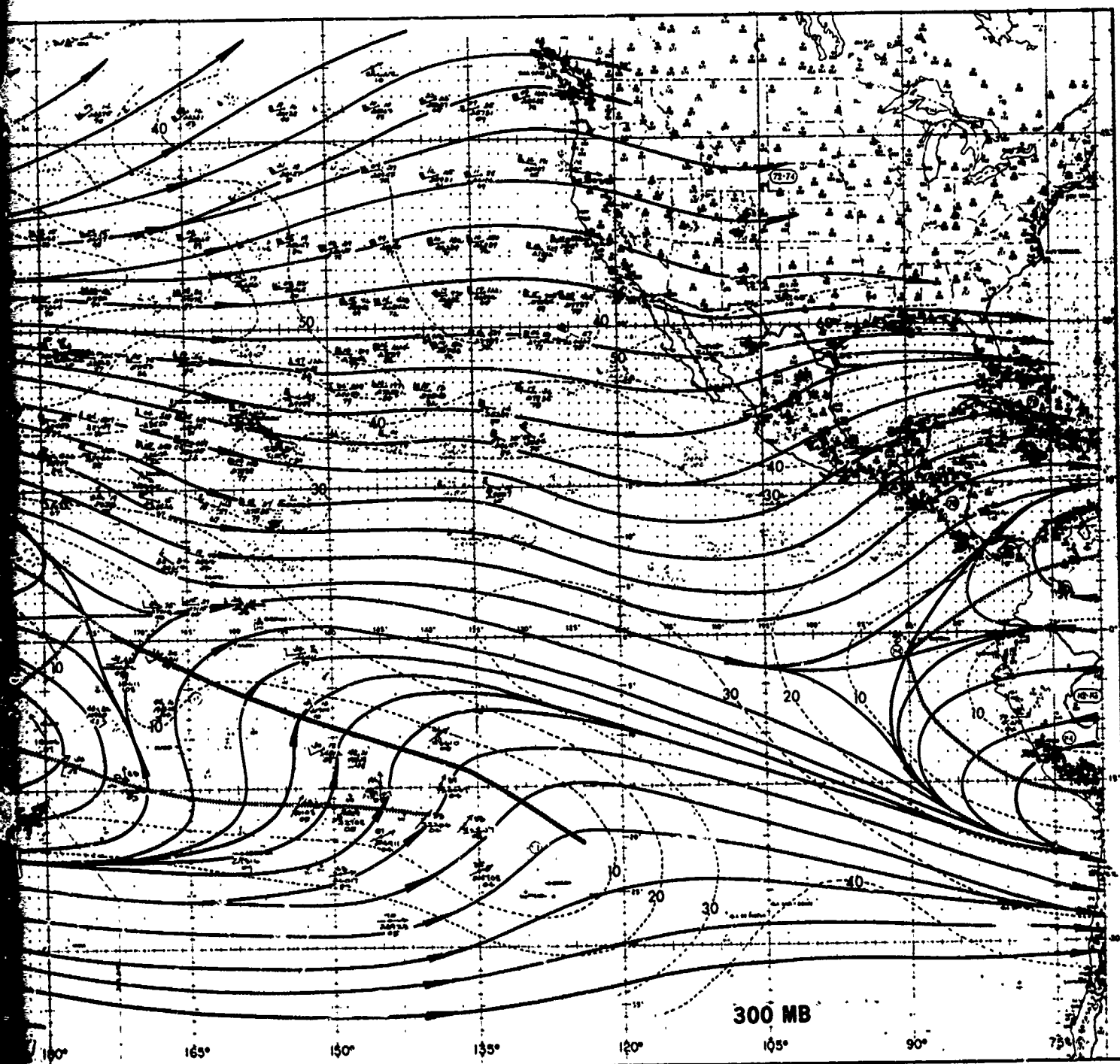
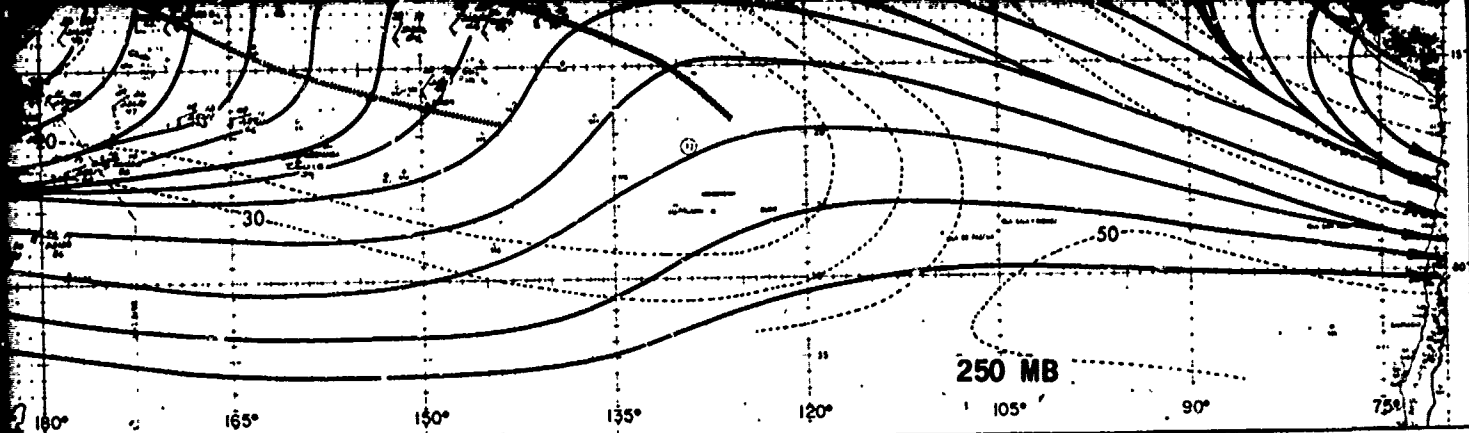
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NN	-number of years of record

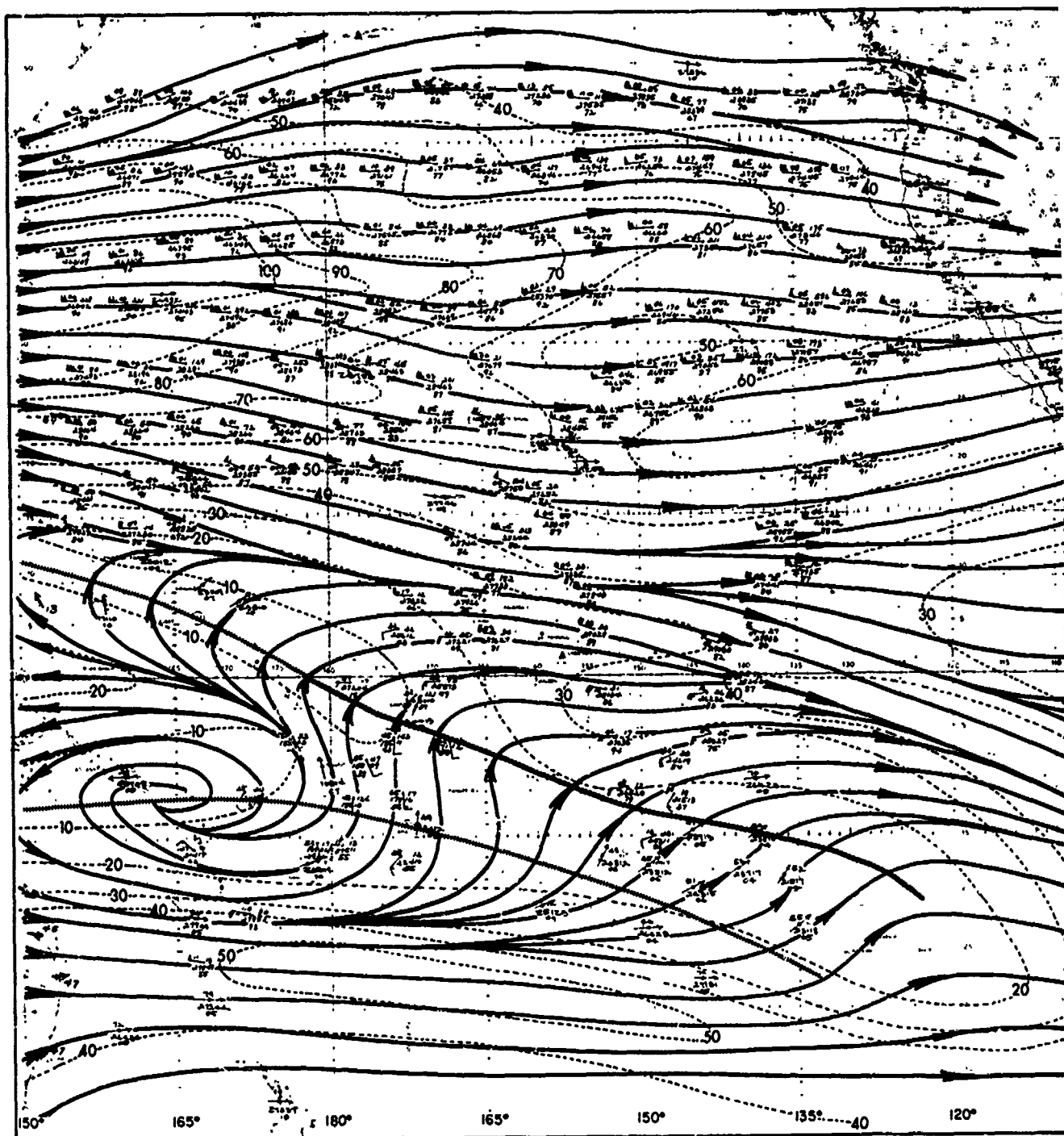
Rawins

SS

 dddfff
 NN









MARCH

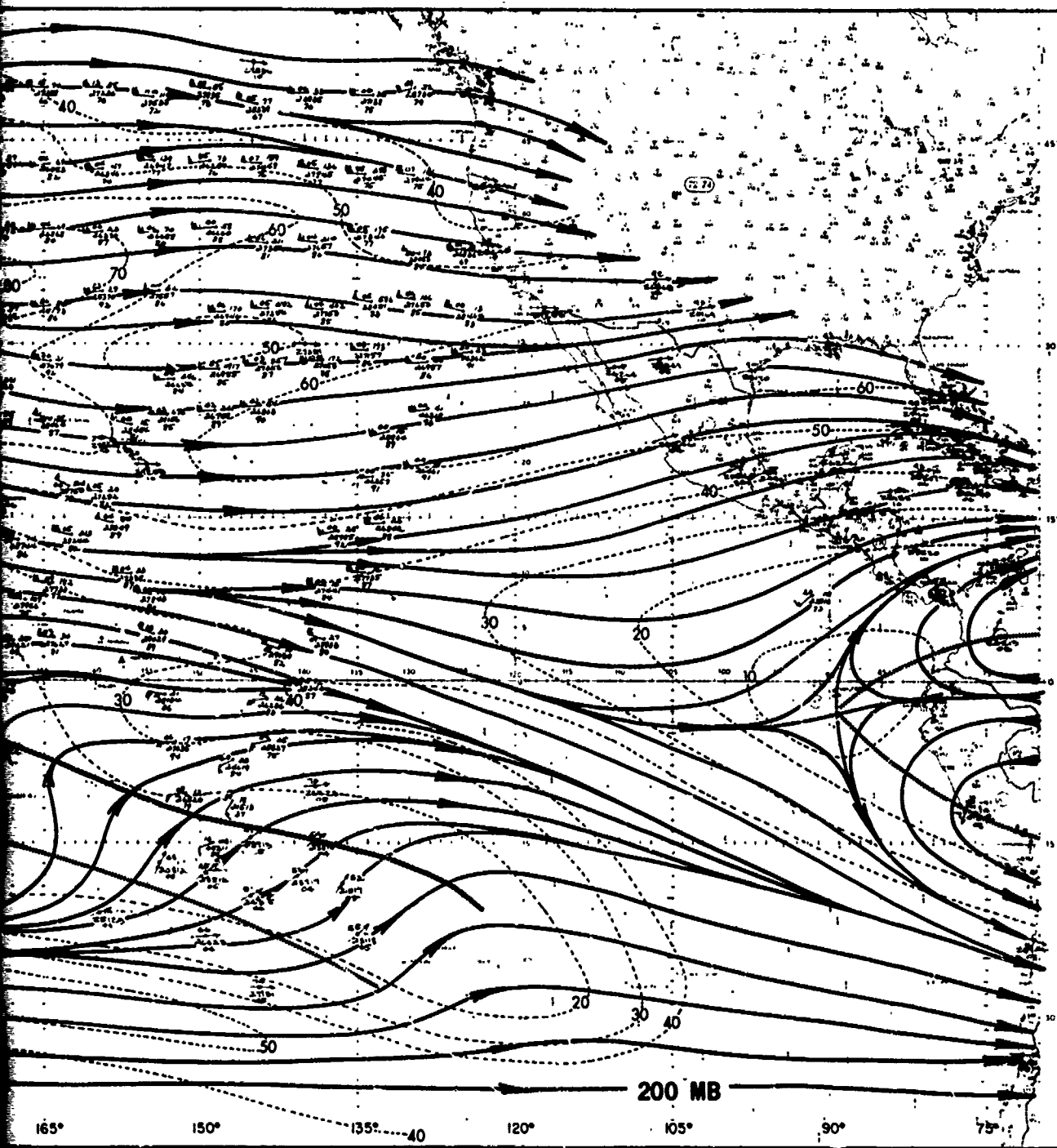
Northern Hemisphere

Considerable changes occur in the temperate westerlies from February to March. As from January to February the major changes are in the speed field. The jet core along 155E has moved northward to near 36N, and the speed has decreased to about 110 kt. There is a more pronounced separation between the northern branch extending east-northeast from the jet core and the southern branch from Hawaii to Baja California. Even though the jet core has moved northward and

The subtropical ridge is farther south than in February. The jet core is now west of 180, or at

Southern Hemisphere

The subtropical ridge is now farther south than in February. The jet core is now west of 180, or at



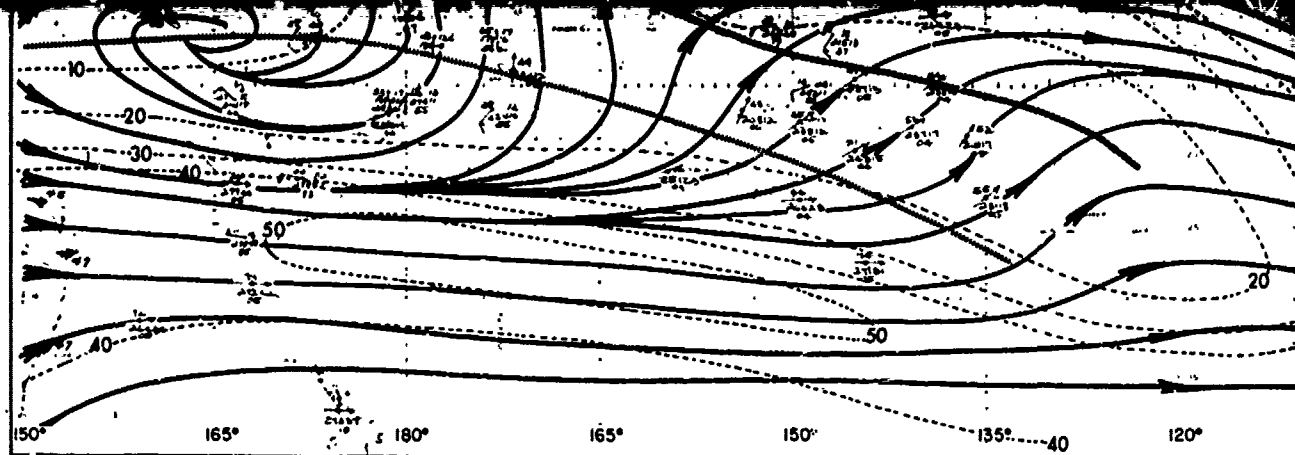
MARCH

westerlies from
the major changes are
moved northward to
110 kt. There is a
branch extending east-
ward from Hawaii to
moved northward and

The subtropical ridge is near 10N at 155E, or some three degrees farther south than in February. It joins with the Southern Hemisphere TUTT west of 180, or about 10 degrees farther west than in February.

Southern Hemisphere

The subtropical ridge is near the February position of 12S at 155E. From 175E to 165W it is more pronounced than in February as indicated by the increased easterly component of the tropical easter-



MARCH

Northern Hemisphere

Considerable changes occur in the temperate westerlies from February to March. As from January to February the major changes are in the speed field. The jet core along 155E has moved northward to near 36N, and the speed has decreased to about 110 kt. There is a more pronounced separation between the northern branch extending east-northeast from the jet core and the southern branch from Hawaii to Baja California. Even though the jet core has moved northward and weakened some 25 kt from February, the speeds in the latitudes of 15N to 20N from Wake Island through Johnston Island to south of Hawaii have increased some 10 kt.

There are subtle changes in the direction field from February; i.e., the backing of more than 10 degrees in the Johnston-Hawaiian Island region; however, there are no pronounced troughs or ridges. The ridging in higher latitudes which was prominent in January and February off the west coast of North America has moved westward of weather ship Papa (50N, 145W) and become less pronounced.

The subtropical ridge has moved farther south than in February, and is now centered west of 180, or at 175E.

Southern Hemisphere


The subtropical ridge has moved farther south than in February, and is now centered west of 180, or at 175E. From 175E to 160E, the ridge is indicated by the increase in wind speed between the ridge and the jet core.

The temperate westerlies have moved farther south from February to great effect. Over western South America, the wind speed has decreased to less than 10 kt.

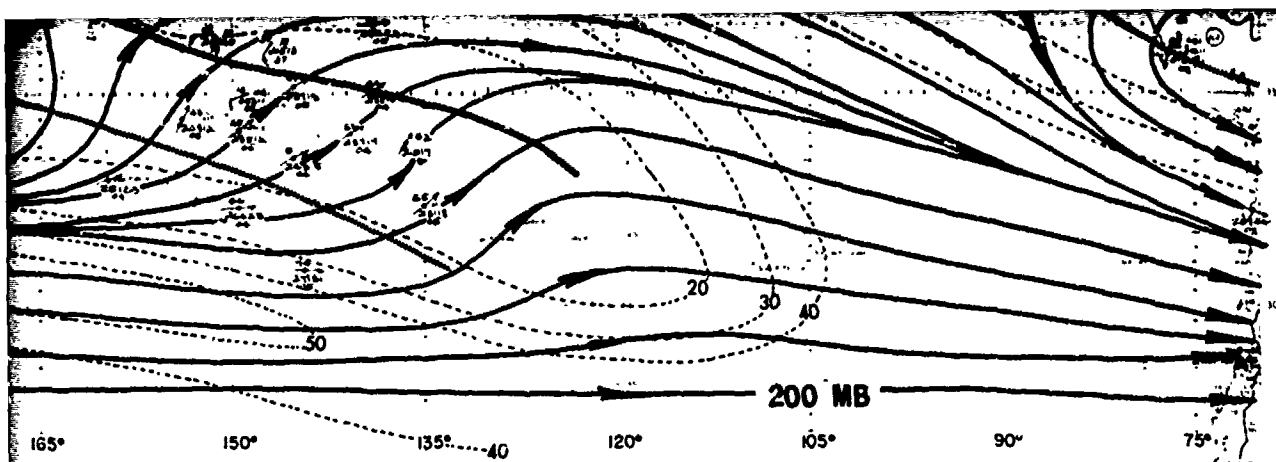
Equatorial Region

The change from February to March is a cyclonic cell over South America, which has increased in intensity from February to March. The change is in intensity and latitude.

PIREP Winds

EE nnnn

 dddfff
 SS

EE	-percentage of winds with an east component
nnnn	-number of observations
ddd	-mean resultant wind direction
fff	-mean resultant wind speed in knots (flag = 50 knots, long barb = 10 knots, short barb = 5 knots)
SS	-steadiness of winds in percent
NN	-number of years of record



MARCH

The subtropical ridge is near 10N at 155E, or some three degrees farther south than in February. It joins with the Southern Hemisphere TUTT west of 180, or about 10 degrees farther west than in February.

Southern Hemisphere

The subtropical ridge is near the February position of 12S at 155E. From 175E to 165W it is more pronounced than in February as indicated by the increased easterly component of the tropical easterlies between the ridge and the TUTT.

The temperate westerlies over eastern Australia have increased from February to greater than 45 kt. The core lies near 30S as in February. Over western South America the westerly maximum near 35S has decreased to less than 50 kt.

Equatorial Region

The change from equatorial easterlies to westerlies occurs near 177E or some 10 degrees farther west than in February. The anticyclonic cell over South America south of the equator has decreased in intensity from February, and the equatorial easterlies have decreased in intensity and latitudinal extent.

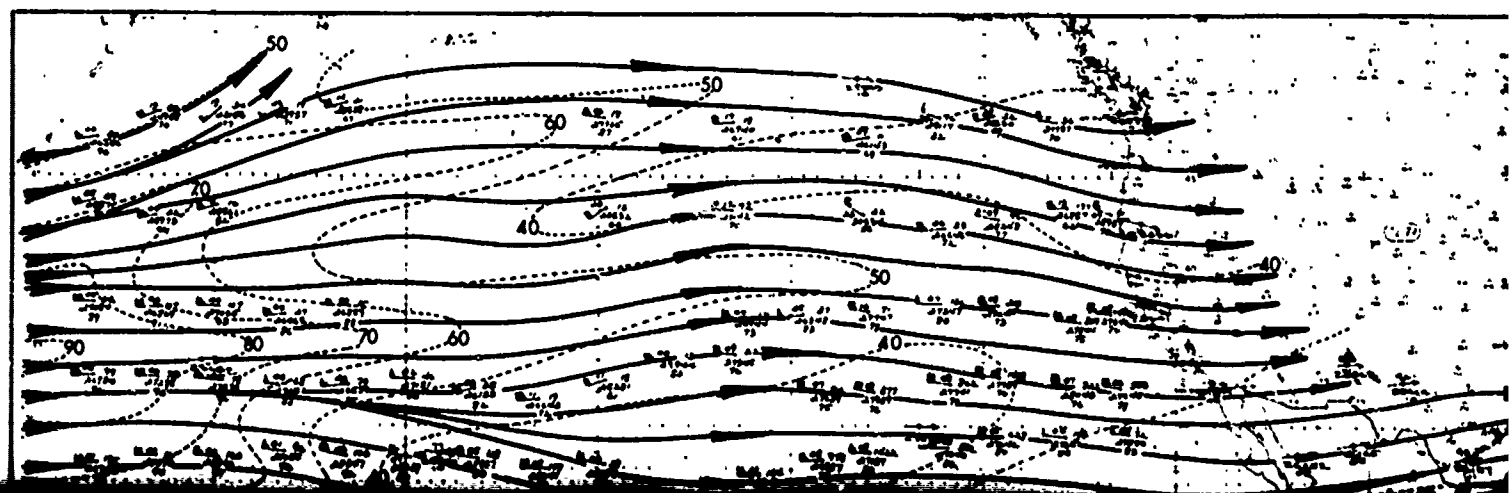
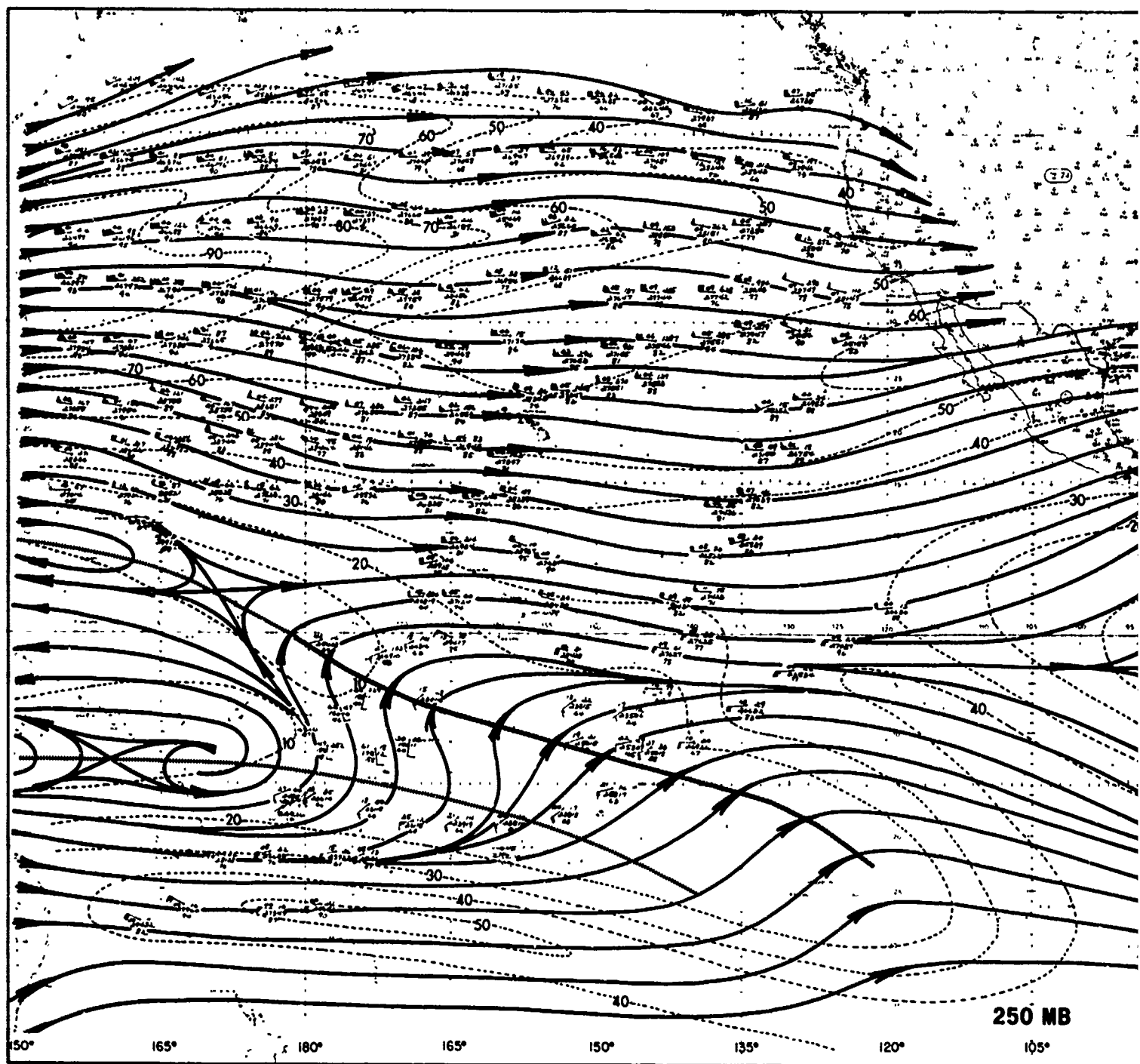
westerlies from the major changes are moved northward to 10 kt. There is a branch extending east-north from Hawaii to 10 kt. moved northward and the latitudes of 15N to south of Hawaii

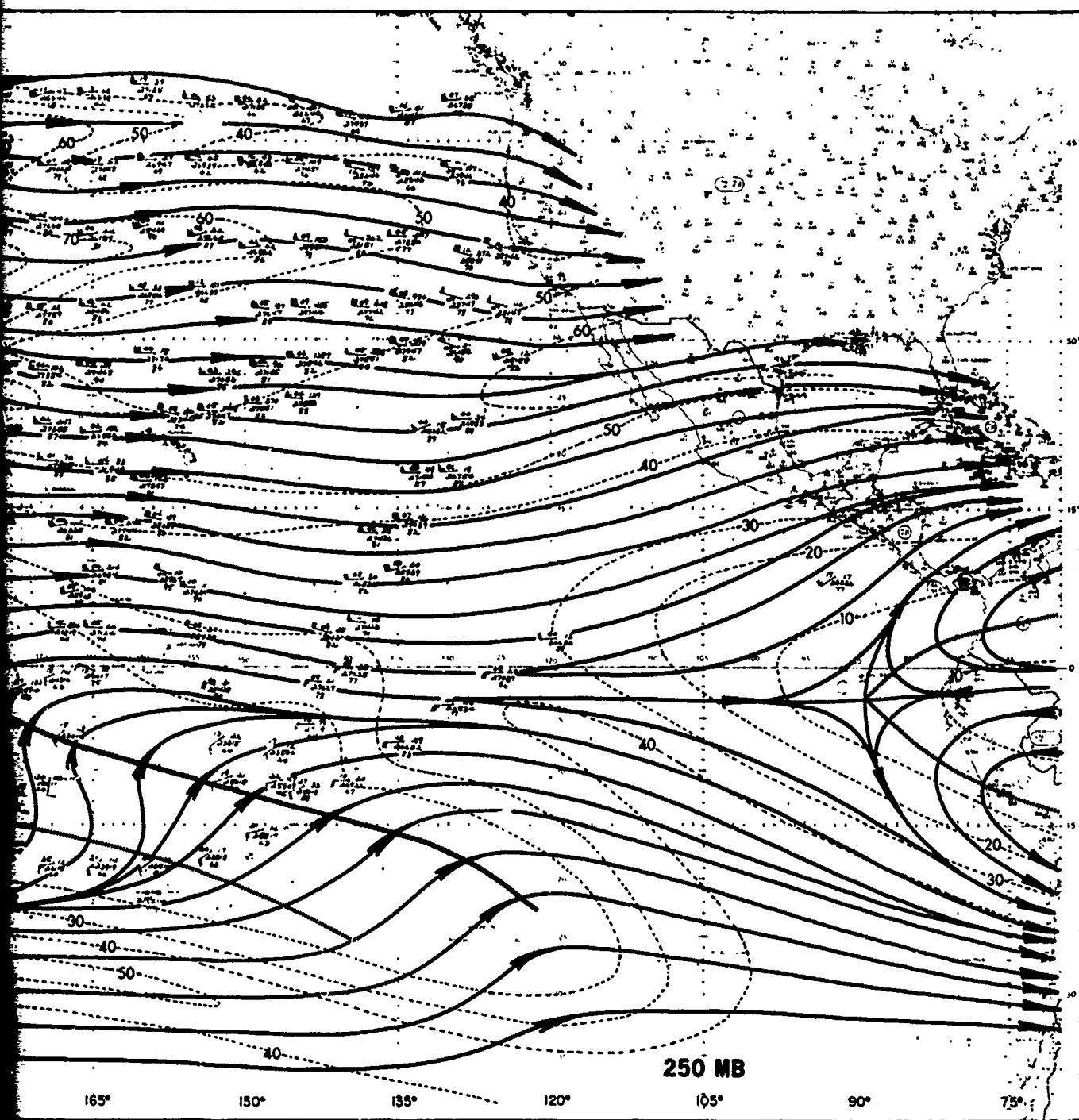
field from February;
Johnston-Hawaiian
troughs or ridges.
ent in January and
moved westward of
pronounced.

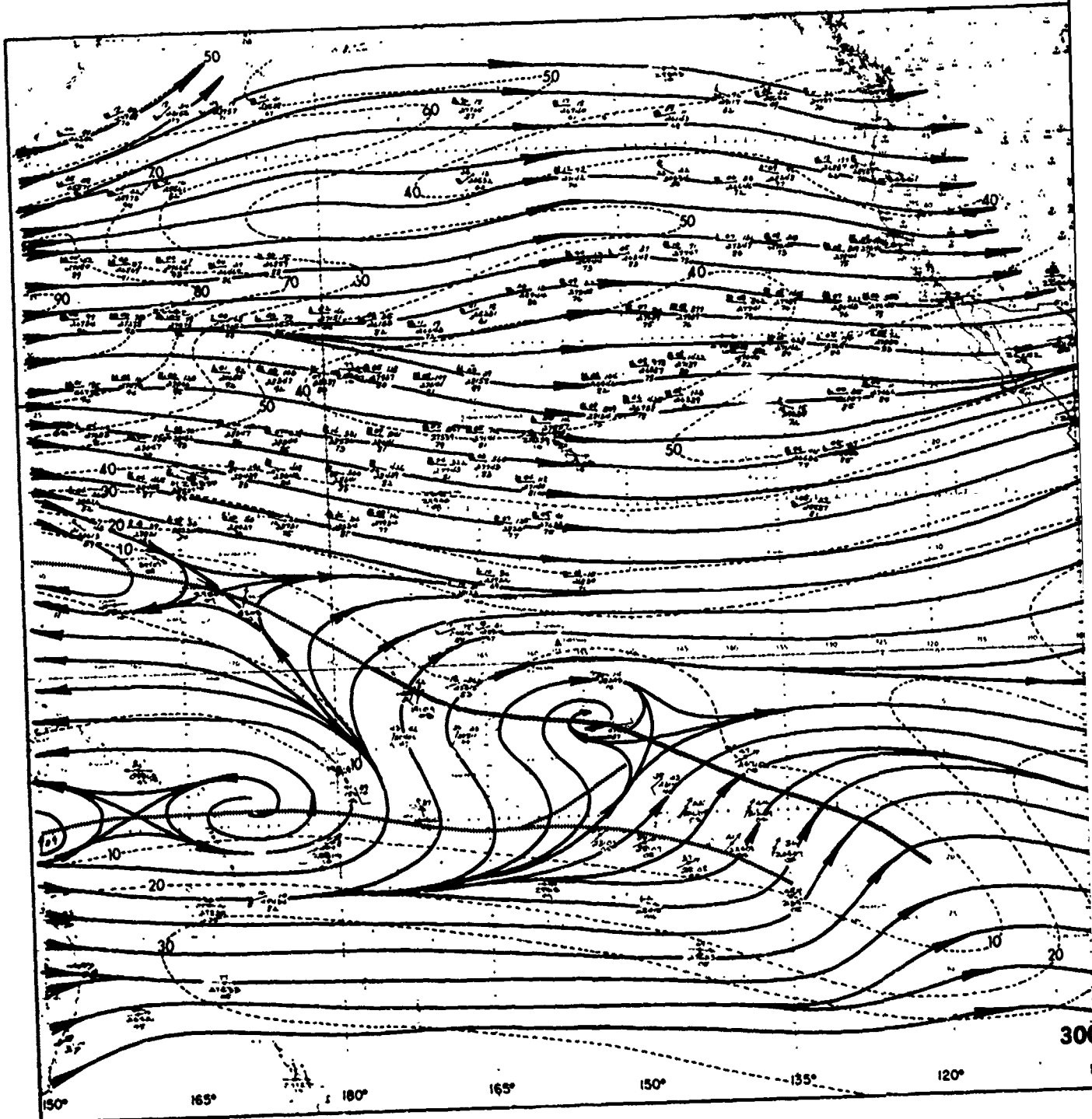
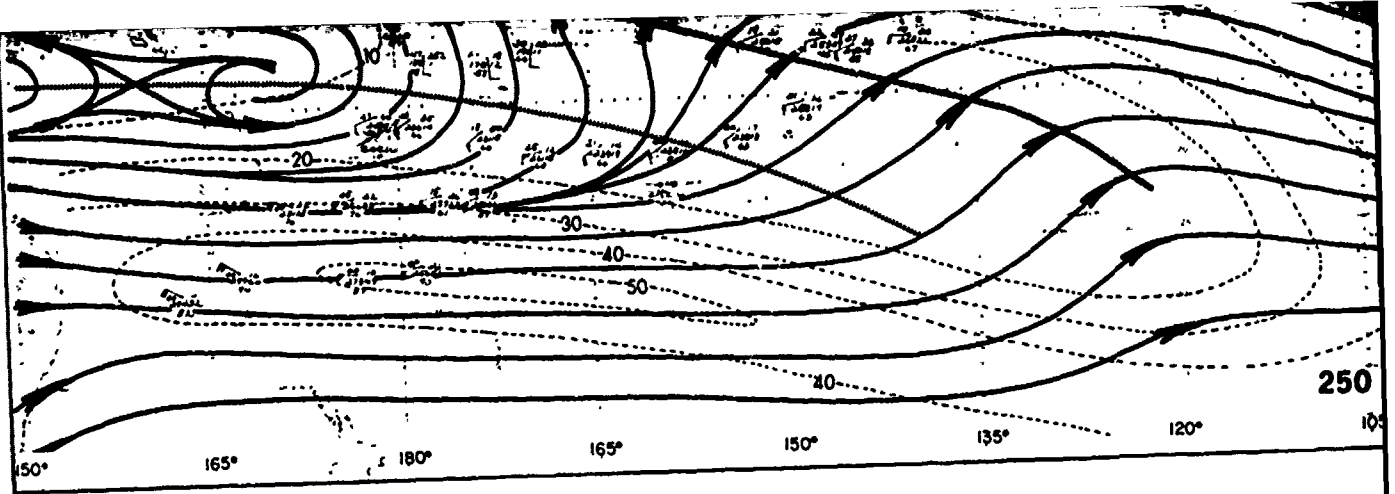
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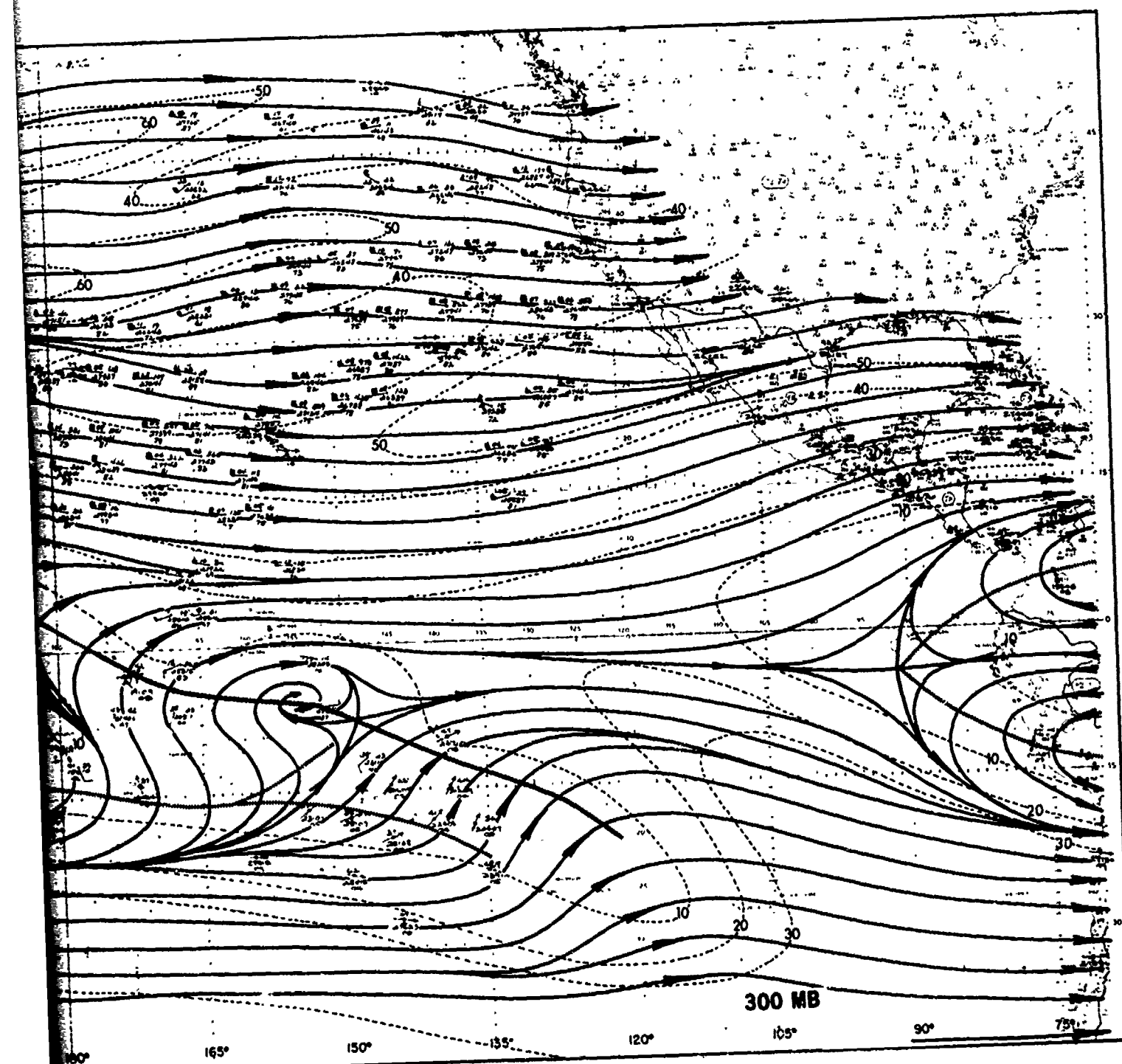
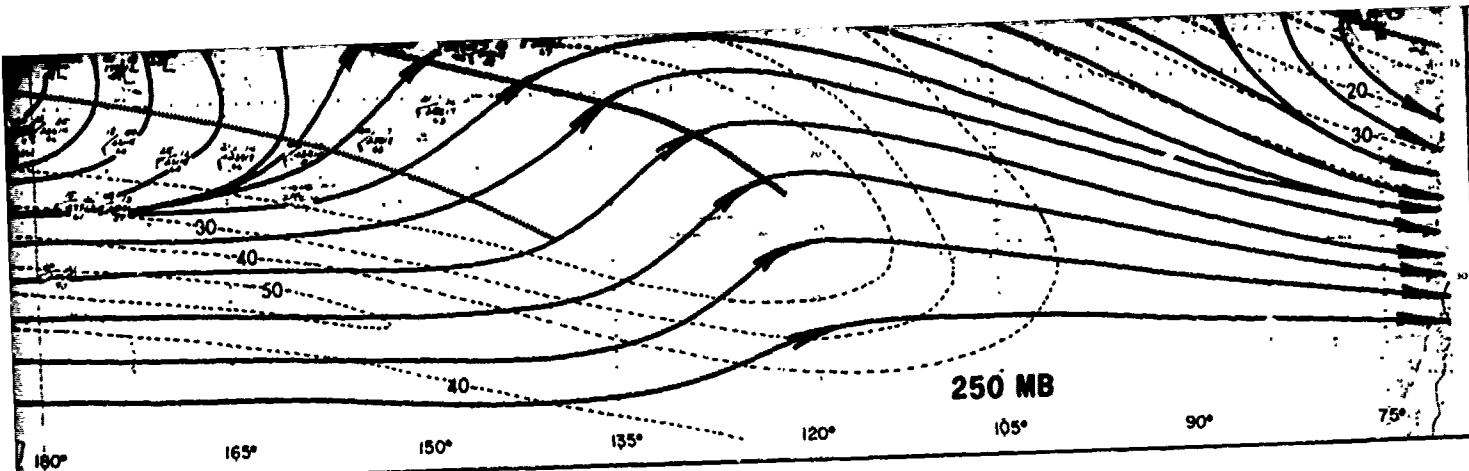
Rawins

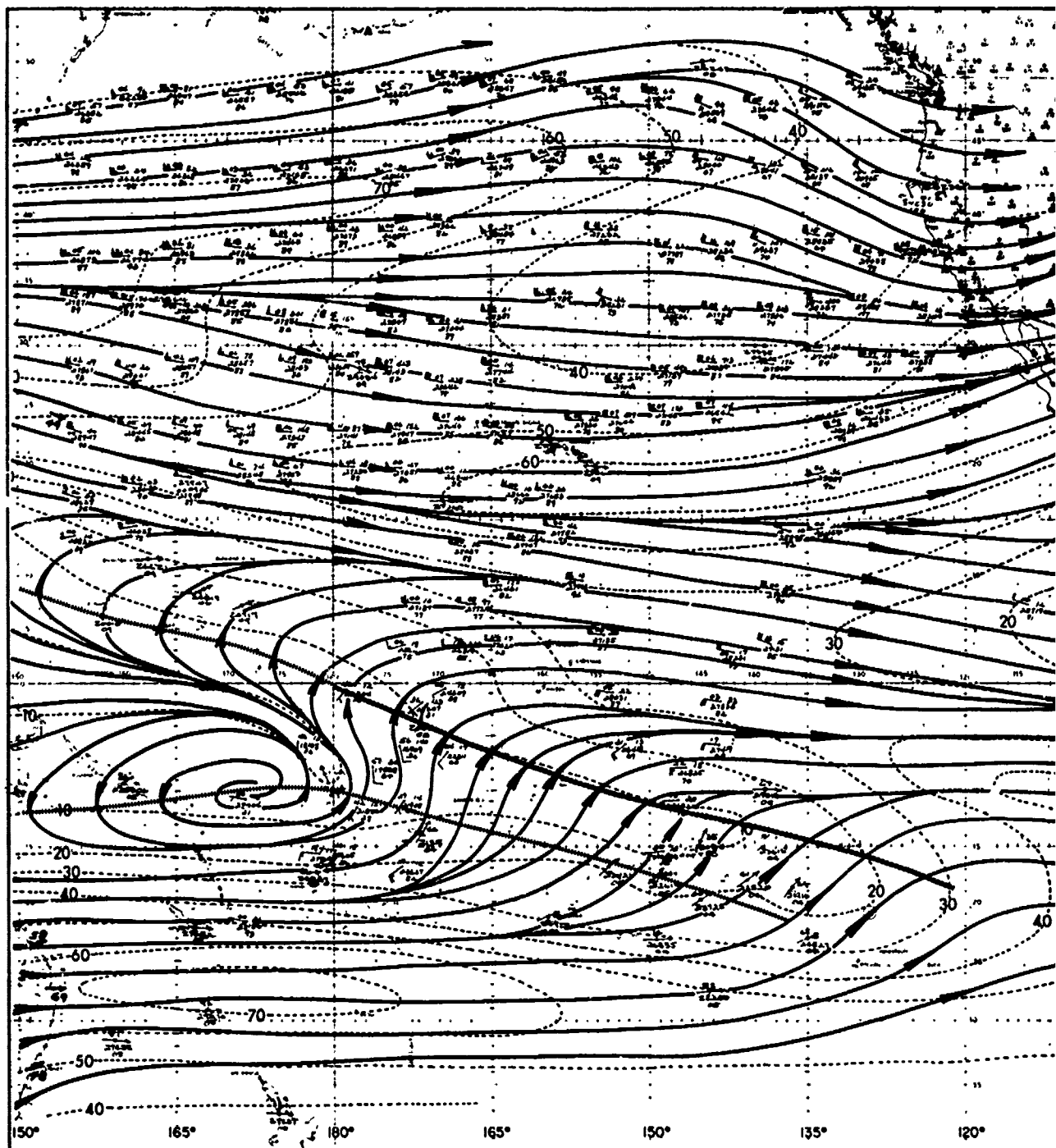
SS
ddff
NN











APRIL

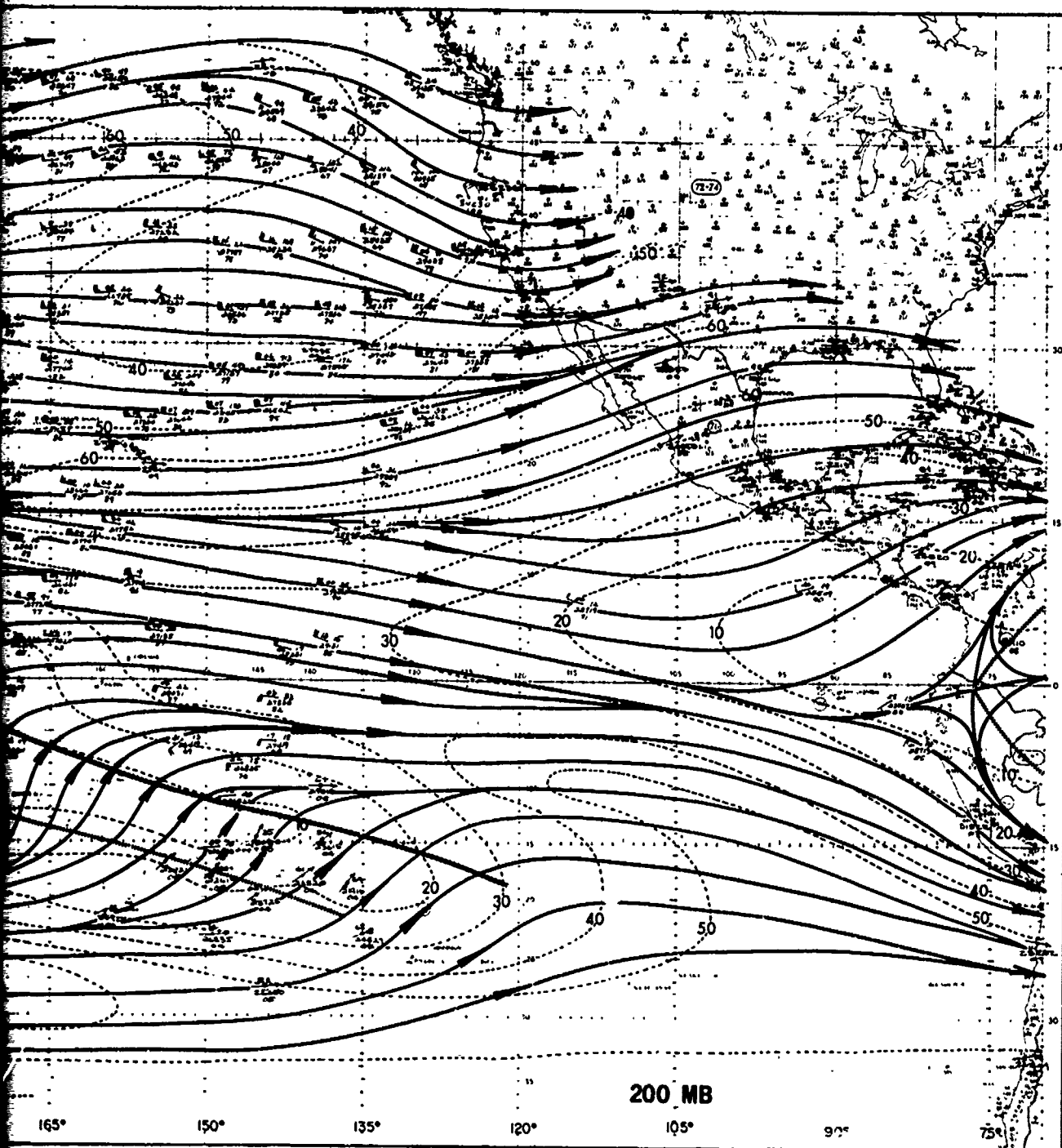
Northern Hemisphere

The separation trend between the two main streams of the westerlies, which is quite apparent from February to March, continues from March to April. The maximum core of the temperate westerlies has continued its northward movement to 38N at 155E; and the speed has decreased to about 75 kt. The southern current has continued to move southward in the Johnston-Hawaii region to near 18N. The current

The subtropical at 155E. It joins the March.

Southern Hemisphere

The subtropical position of 12S at



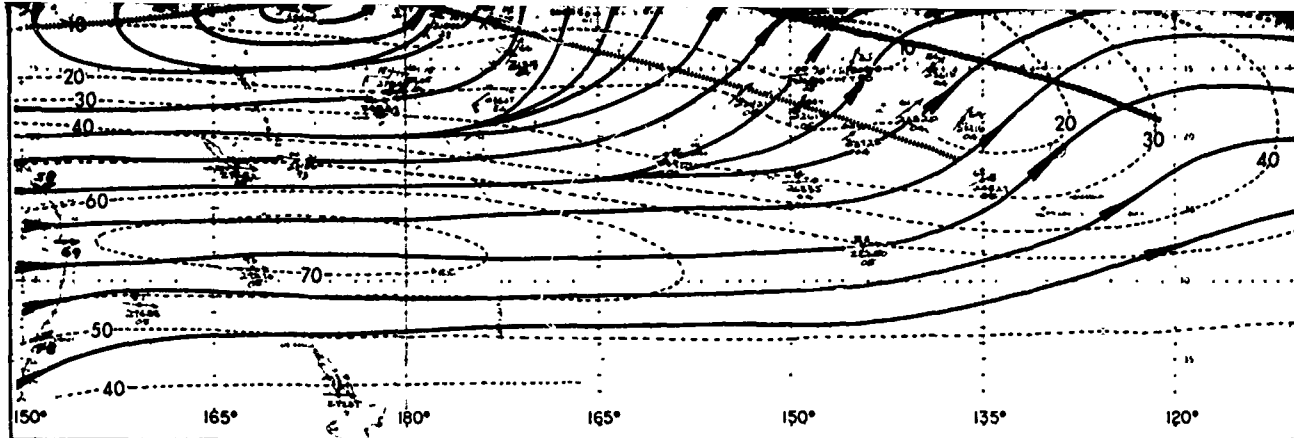
APRIL

streams of the wester-
 March, continues from
 the westerlies has con-
 and the speed has
 it has continued to move
 18N. The current
 as in January,

The subtropical ridge has continued to move southward to near 8N at 155E. It joins the Southern Hemisphere TUTT just west of 180 as in March.

Southern Hemisphere

The subtropical ridge remains near the January through March position of 12S at 155E. The ridge has weakened east of 180 in conjunction with apparent weakening of the TUTT.



APRIL

Northern Hemisphere

The separation trend between the two main streams of the westerlies, which is quite apparent from February to March, continues from March to April. The maximum core of the temperate westerlies has continued its northward movement to 38N at 155E; and the speed has decreased to about 75 kt. The southern current has continued to move southward in the Johnston-Hawaii region to near 18N. The current crosses Baja California at about the same latitude as in January, February and March. The speed of the current has also continued to increase in the Johnston-Hawaii region such that both Johnston Island and Hilo, Hawaii record their greatest mean monthly speed in April. The wind minimum area between the two currents has continued to expand over the eastern Pacific and is much more pronounced than in March. The separation of the southern current from the temperate westerlies is sufficient to justify labelling it "subtropical westerlies."

The ridge in the northern latitudes has moved back eastward to just east of weather ship Papa (50N, 145W) and the pronounced veering of the winds off the Oregon and Washington coasts indicates a deeper trough over the western United States than in the previous month.

The subtropical at 155E. It joins the March.

Southern Hemisphere


The subtropical position of 12S at 15 junction with apparent

The temperate westerlies just east of Australia March to near 28S. They have moved north of 3

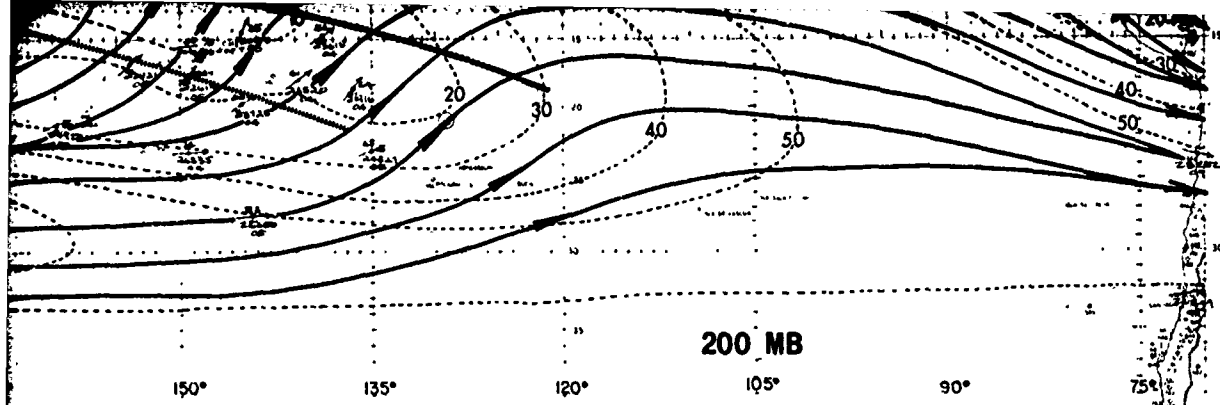
Equatorial Region

The direction pattern over the eastern Pacific South America south of 10S thereby reducing

PIREP Winds

EE nnnn

 dddfff
 SS

EE	-percentage of winds with an east component
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SS	-steadiness of winds in percent
NN	-number of years of record



APRIL

The subtropical ridge has continued to move southward to near 8N at 155E. It joins the Southern Hemisphere TUTT just west of 180 as in March.

Southern Hemisphere

The subtropical ridge remains near the January through March position of 12S at 155E. The ridge has weakened east of 180 in conjunction with apparent weakening of the TUTT.


The temperate westerlies have increased in core speed to some 70 kt just east of Australia and have shifted slightly equatorward from March to near 28S. The temperate westerlies over western South America have moved north of 30S and increased to greater than 50 kt.

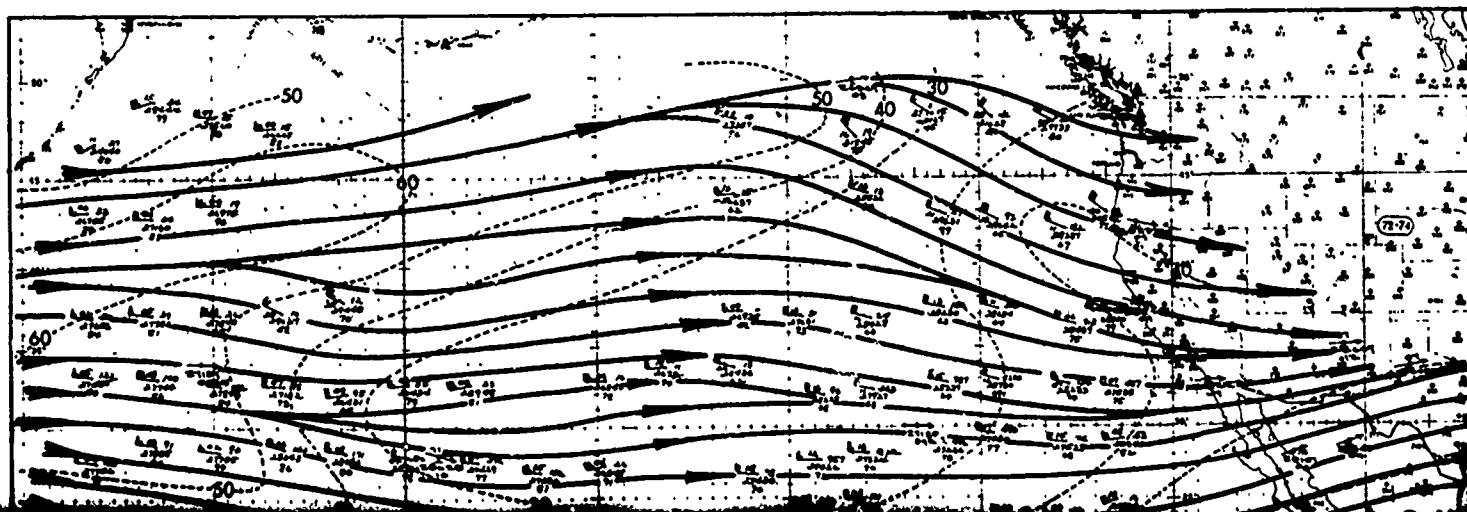
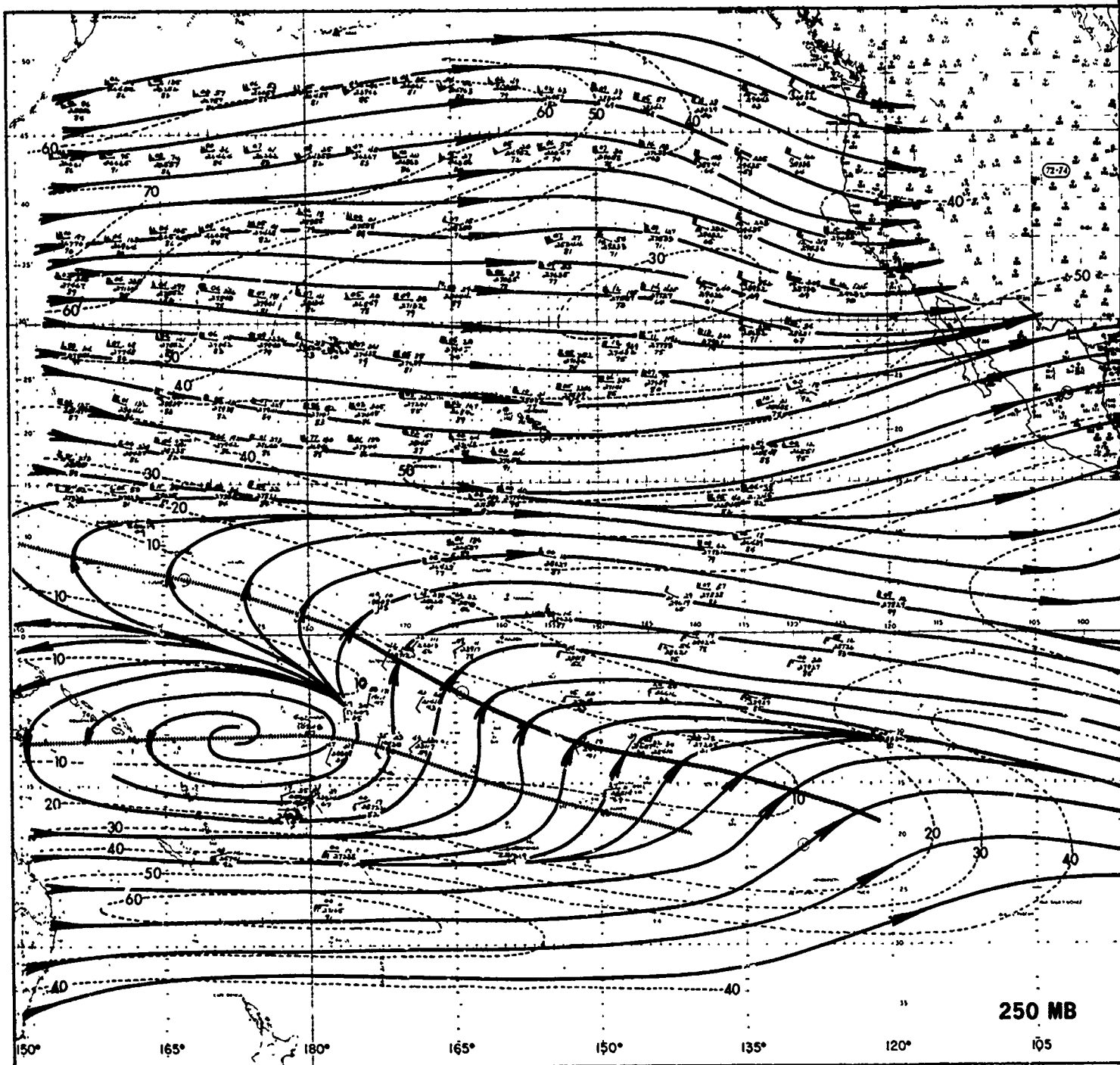
Equatorial Region

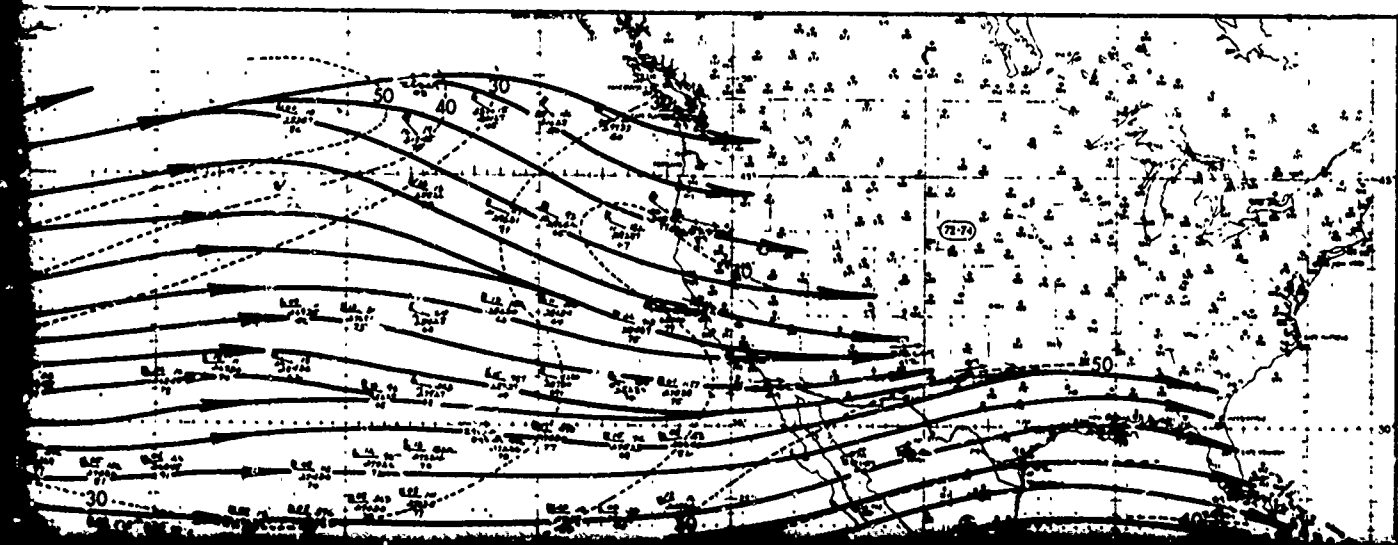
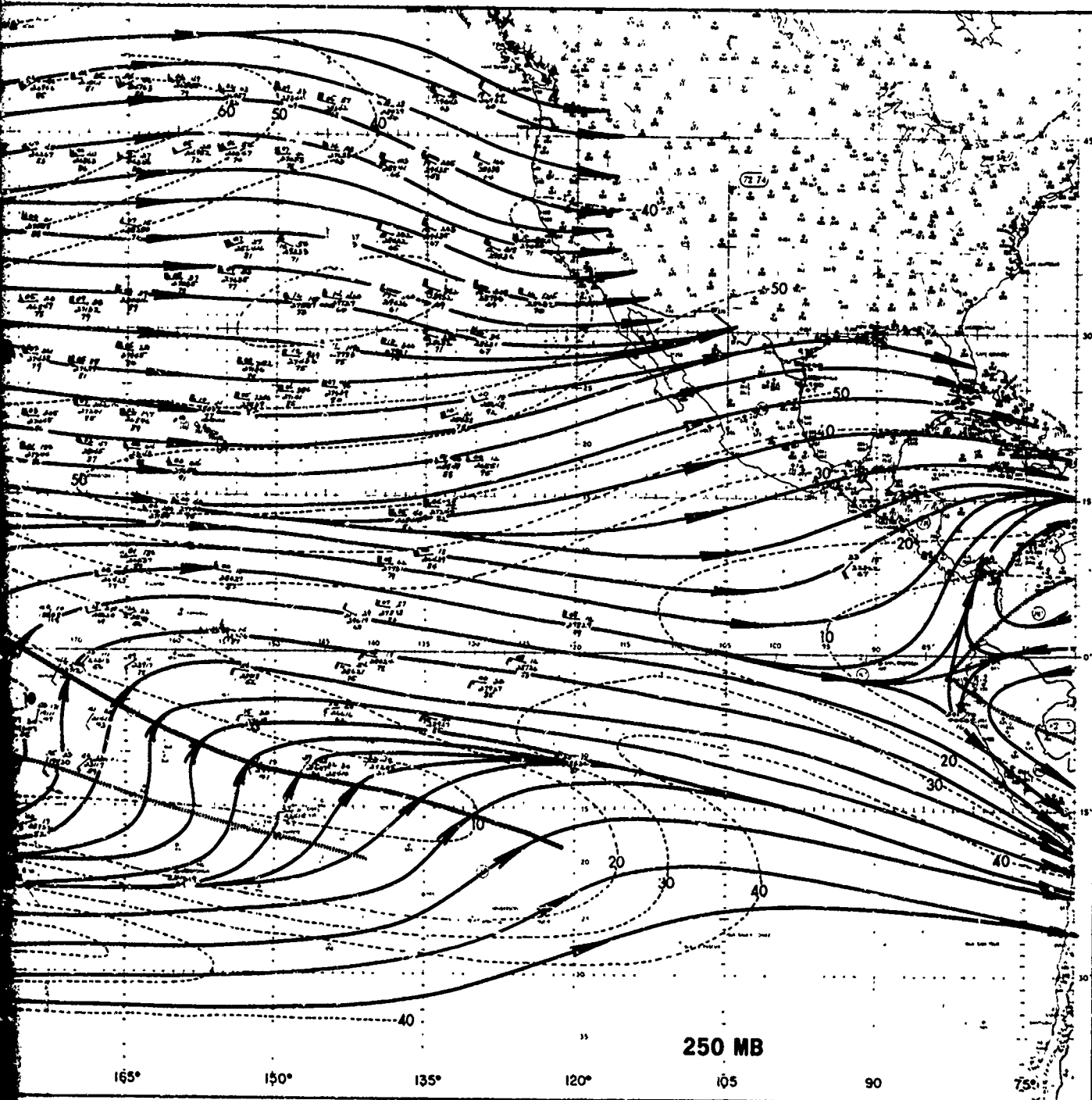
The direction pattern is very similar to that of March. Speeds over the eastern Pacific have decreased. The anticyclonic cell over South America south of the equator has shrunk and moved equatorward of 10S thereby reducing the extent and speed of the equatorial easterlies.

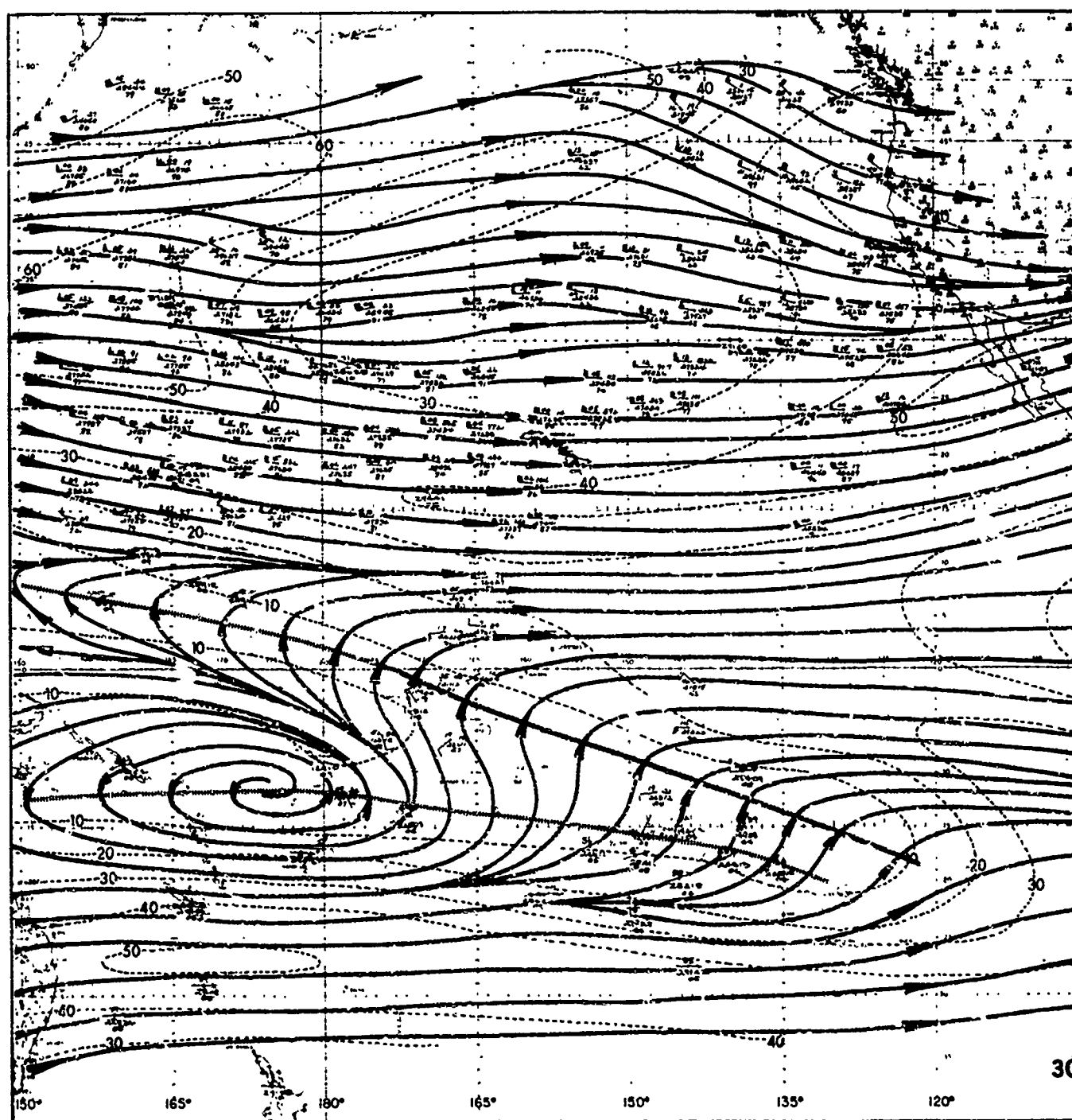
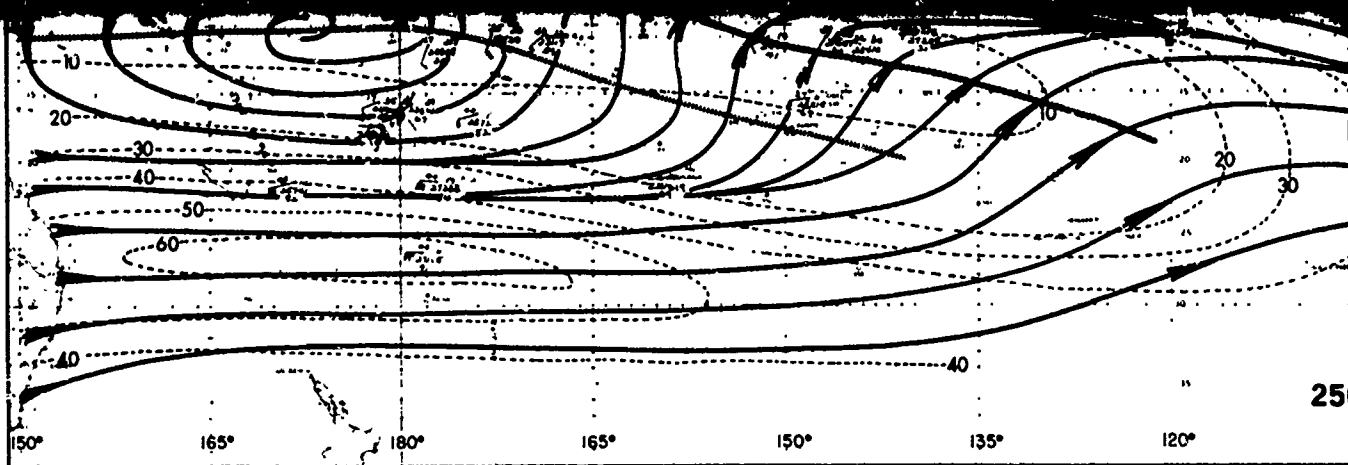
- percentage of winds with an east component
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- steadiness of winds in percent
- number of years of record

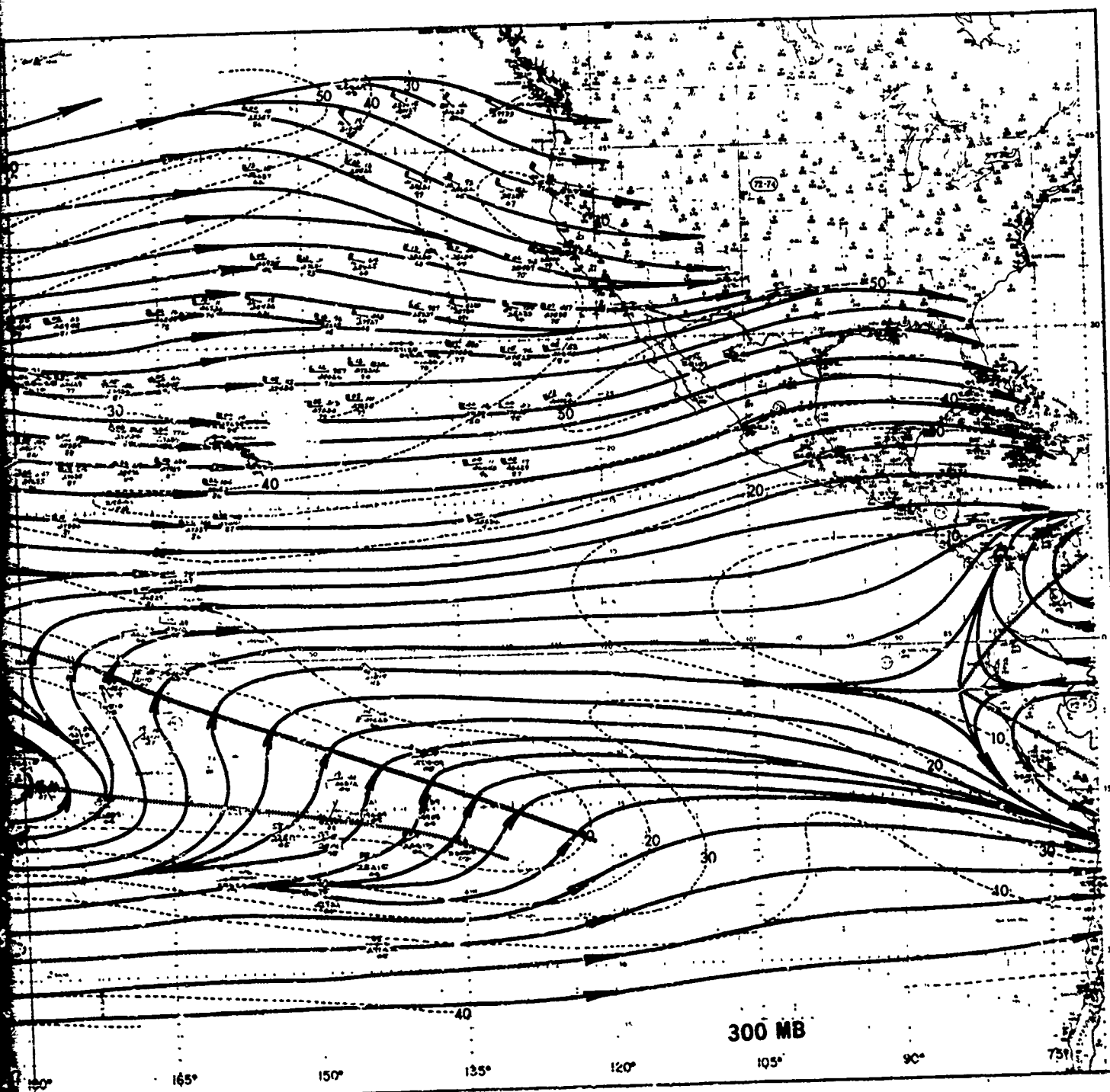
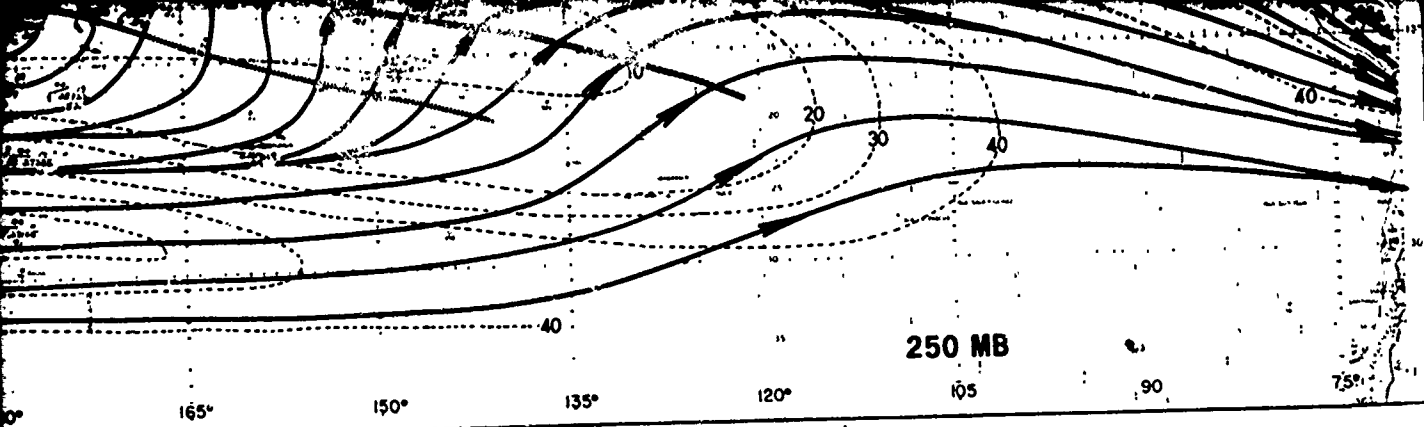
Rawins

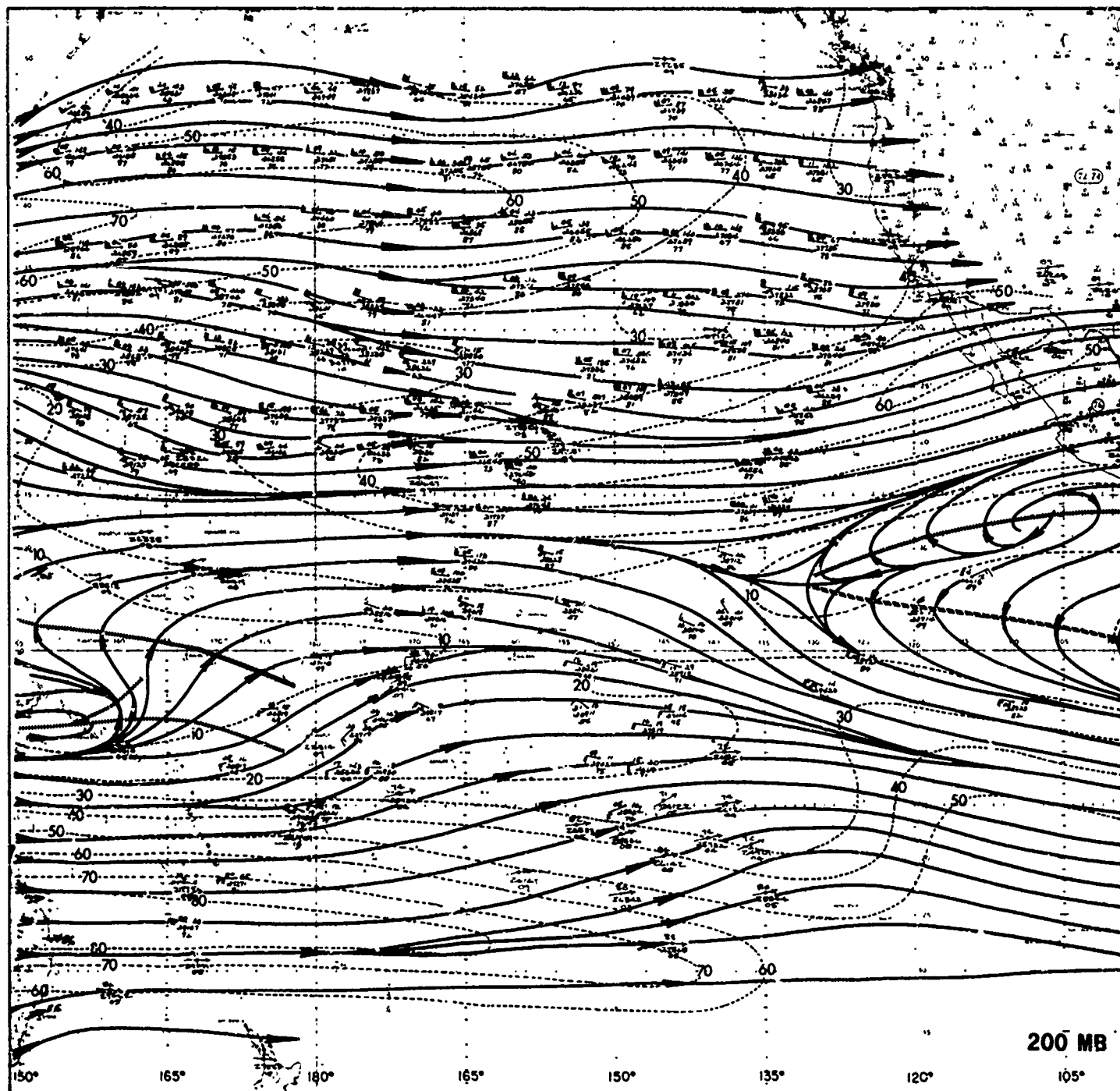
SS

 dddfff
 NN











MAY

Northern Hemisphere

The temperate westerlies have continued to decrease in speed and extent. The core speed of near 70 kt is found near the April position of 38N at 155E.

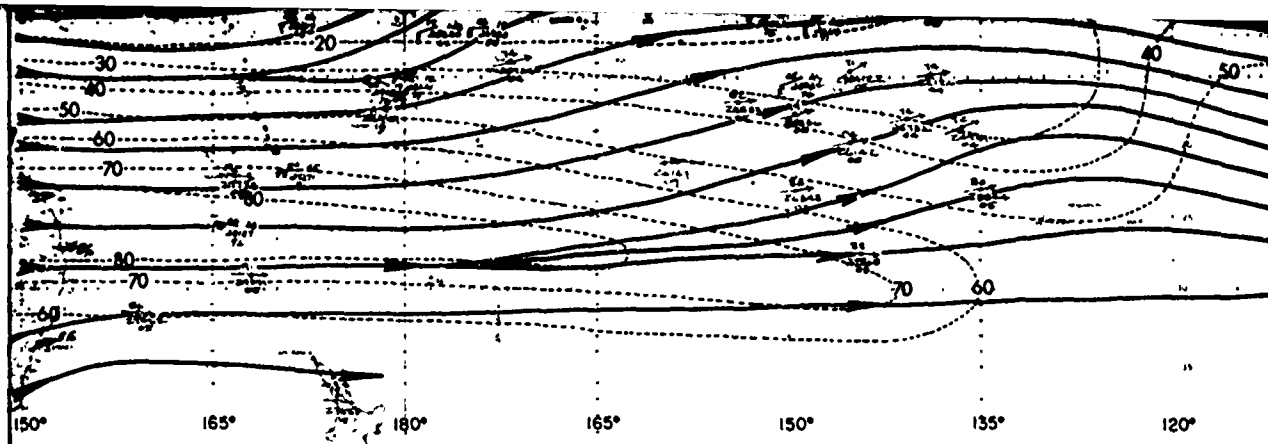
The core of the subtropical westerlies is also near the April position. The speed has decreased to near 50 kt in the Hawaiian region and 60 kt over Baja California.

A segment of the subtropical Pacific and extends westward to is near 14N at 105W. The segment remained near 5N.

Southern Hemisphere

The subtropical ridge has 155E and has shrunk westward;

The TUTT has weakened on



MAY

Northern Hemisphere

The temperate westerlies have continued to decrease in speed and extent. The core speed of near 70 kt is found near the April position of 38N at 155E.

The core of the subtropical westerlies is also near the April position. Their speed has decreased to near 50 kt in the Hawaiian region and 60 kt over Baja California.

Speeds in the minimum zone between the temperate and subtropical westerlies have decreased to less than 30 kt.

The Mid-Pacific Trough (MPT) has become weakly apparent in the direction field. It appears as two segments. One extends from just east of Hawaii to the coast of southern California. The other segment extends from northeast of Midway Island southwestward to Wake Island and 18N, 155E.

The subtropical ridge has continued to move equatorward in the western Pacific to its annual southernmost position of 5N at 155E.

A segment of the Pacific and extends is near 14N at 105W remained near 5N.

Southern Hemisphere

The subtropical ridge has shrunk

The TUTT has weakened. A segment remains near 10S, 160W, but is less than in the direction field.

The temperate westerlies over eastern Australia have moved westward to 25S. Over 25S, the speed is greater than 55 kt, and the extent is near 25S.

Equatorial Region

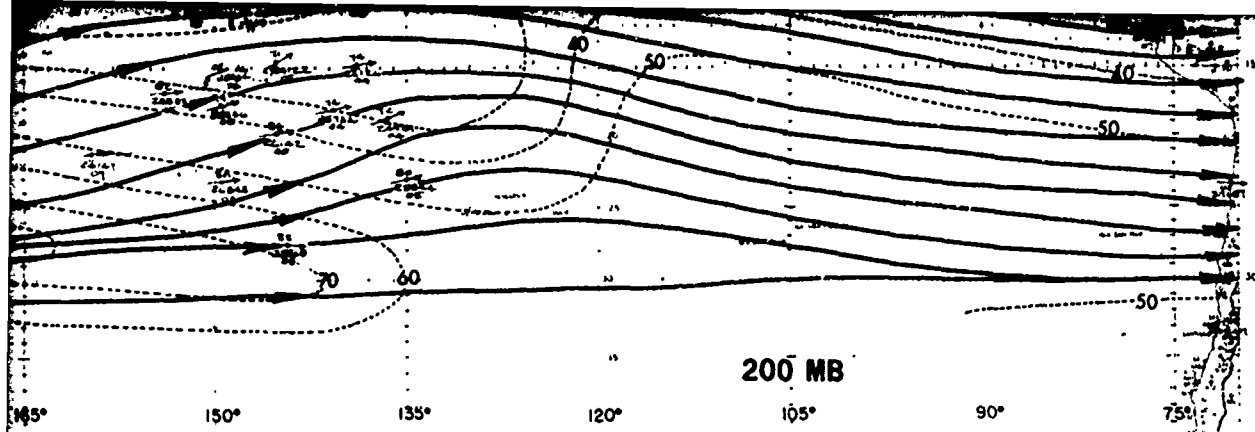
Westward retreat of the equatorial low has moved the region westward to near 160W. The equatorial buffer system has extended the equatorial low to near 95W.

PIREP Winds

EE nnnn

dddfff
SS

EE	-percentage of winds with an east component
nnnn	-number of observations
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SS	-steadiness of winds in percent
NN	-number of years of record



MAY

A segment of the subtropical ridge has formed over the eastern Pacific and extends westward to near 130W. The northernmost position is near 10°N at 105W. The segment of the ridge over South America has remained near 5°N.

Southern Hemisphere

The subtropical ridge has moved sharply equatorward to near 7°N at 155E and has shrunk westward; it is only weakly apparent at 180.

The TUTT has weakened considerably, and it is difficult to locate. A segment remains near 135W and is more apparent in the speed field than in the direction field (note the 250- and 300-mb charts).


The temperate westerlies have increased to greater than 85 kt over eastern Australia, and the core region has moved farther equatorward to 25S. Over western South America speeds have increased to greater than 55 kt, and the core region has moved equatorward to near 25S.

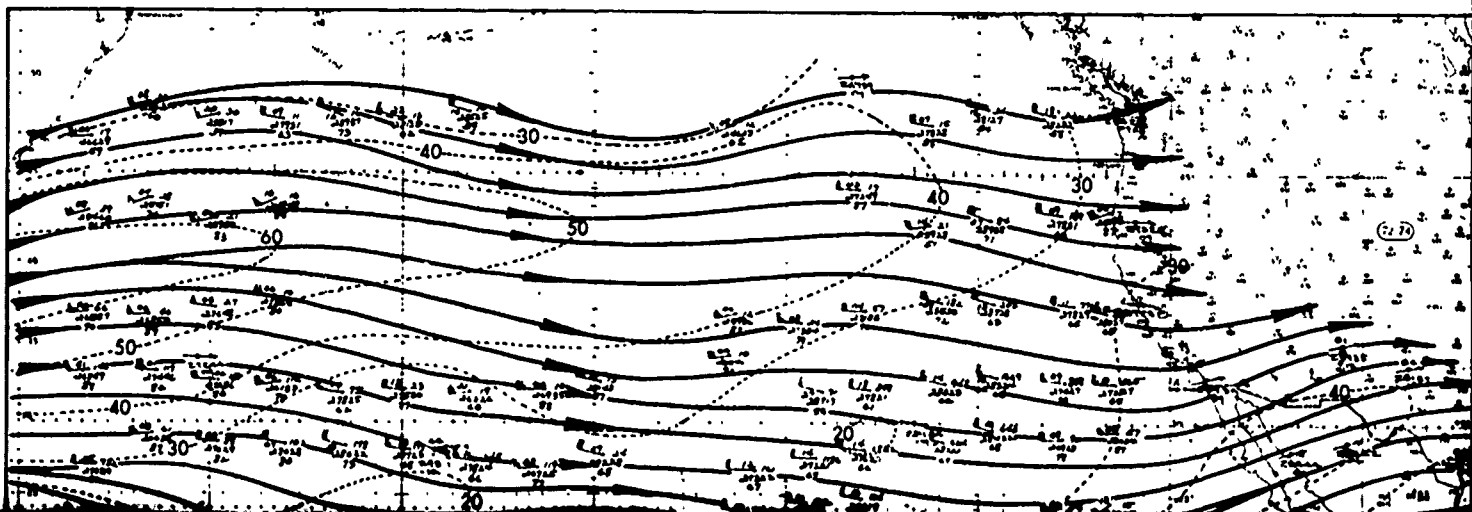
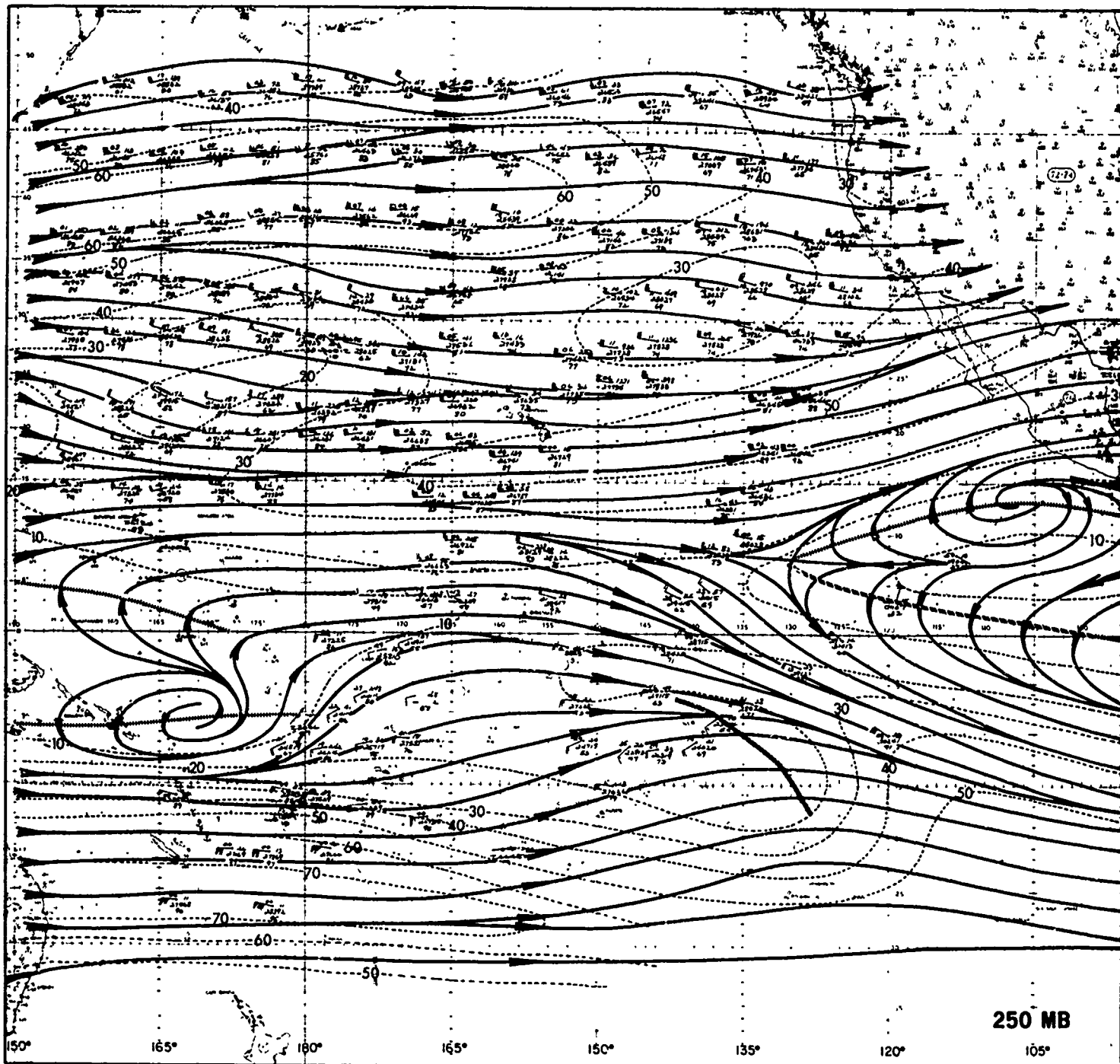
Equatorial Region

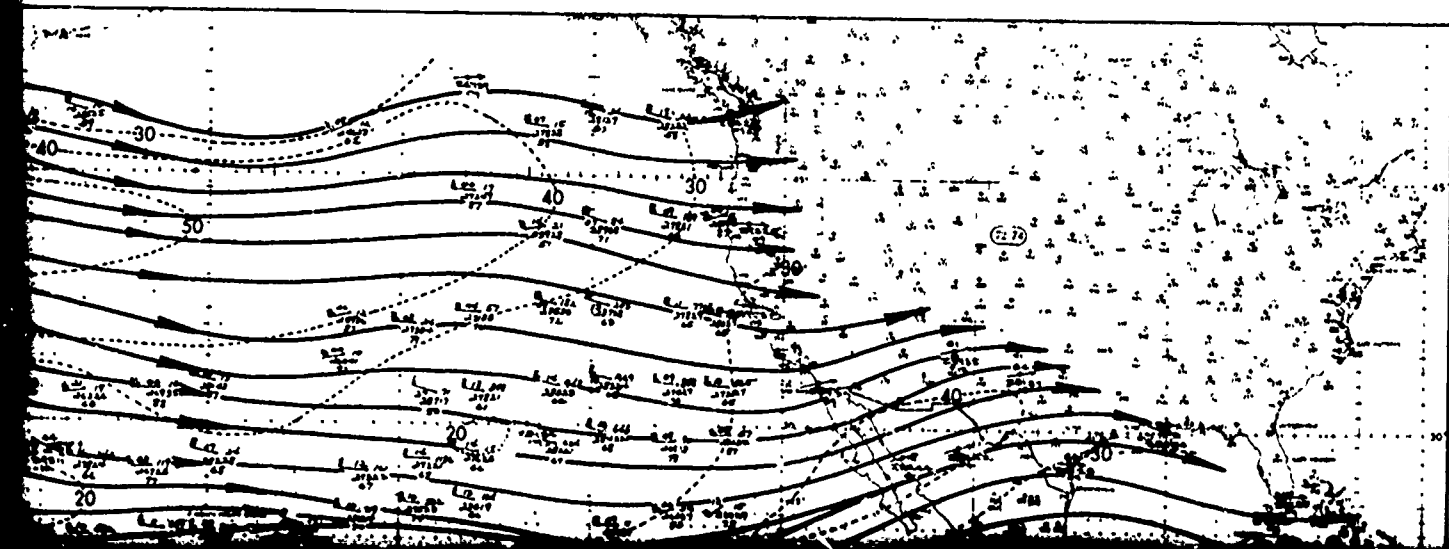
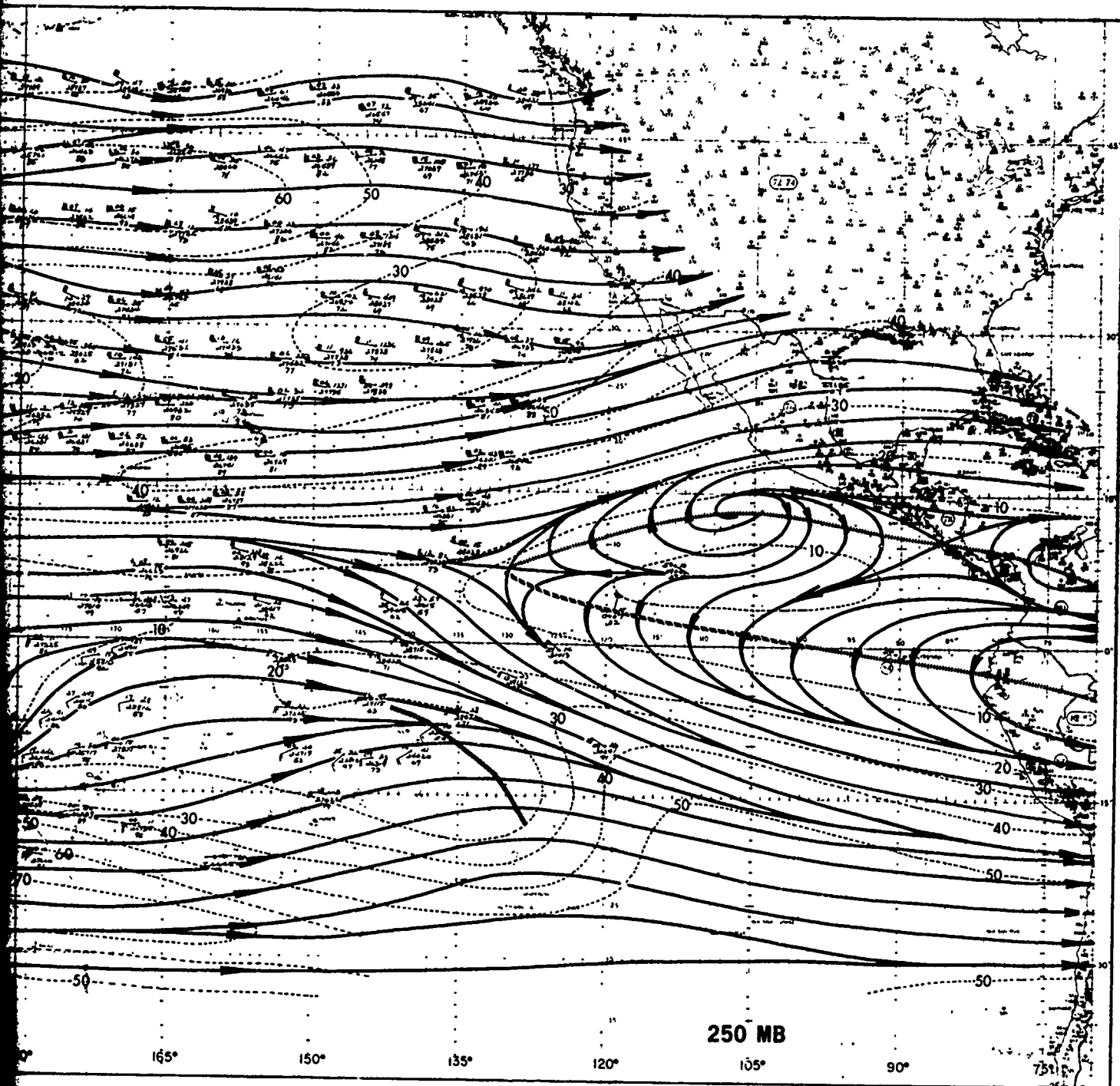
Westward retreat of the subtropical ridges in the western Pacific has moved the region of change from equatorial easterlies to westerlies westward to near 165E. Formation of the ridge in the eastern Pacific has extended the equatorial easterly wind belt westward to near 130W; the buffer system thus formed links with the Southern Hemisphere ridge near 95W.

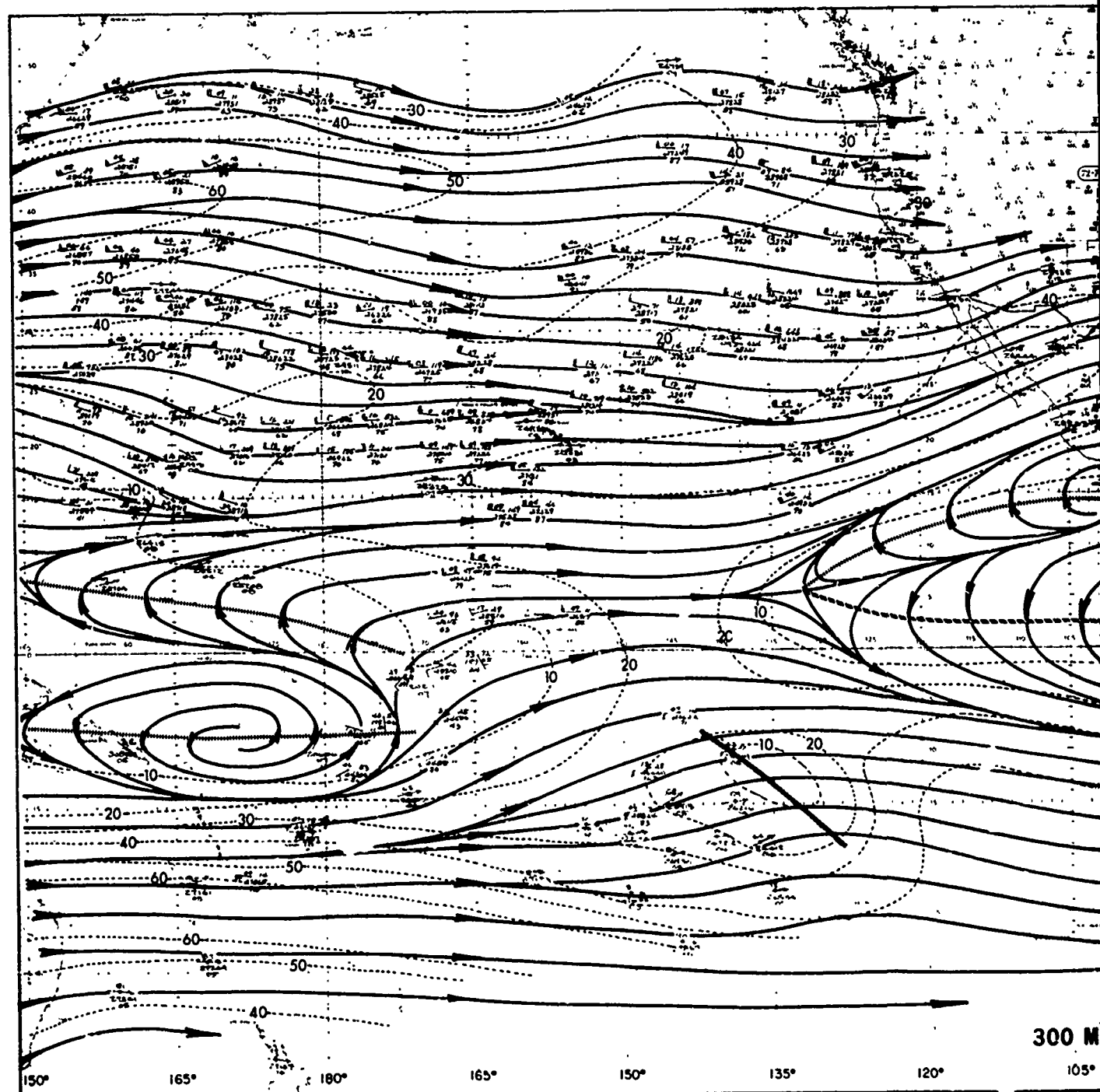
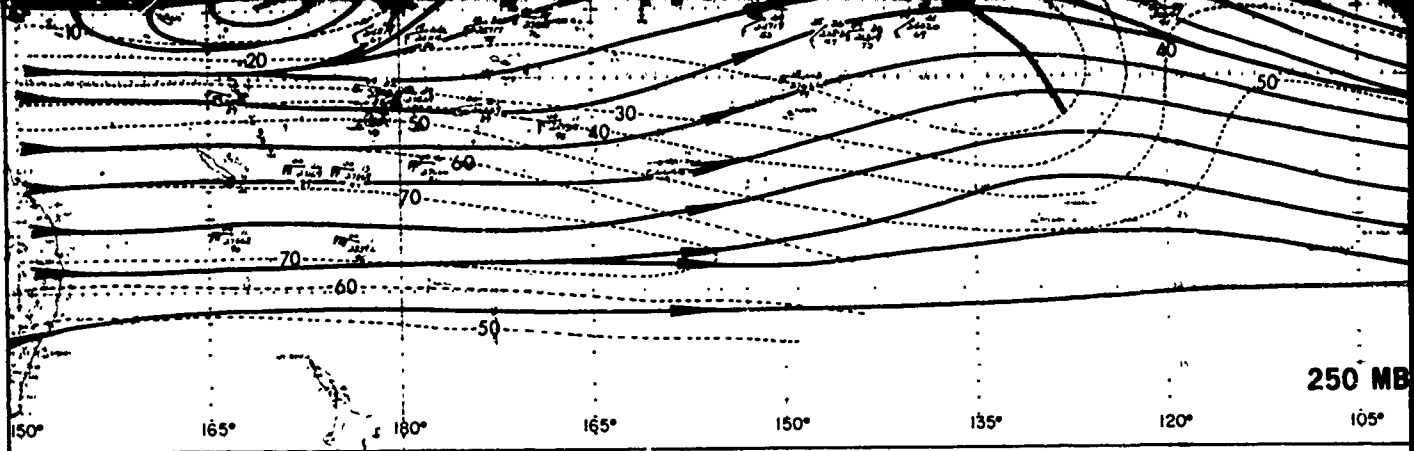
EE	-percentage of winds with an east component
nnnn	-number of observations
ddd	-mean resultant wind direction
fff	-mean resultant wind speed in knots (flag = 50 knots, long barb = 10 knots, short barb = 5 knots)
SS	-steadiness of winds in percent
NN	-number of years of record

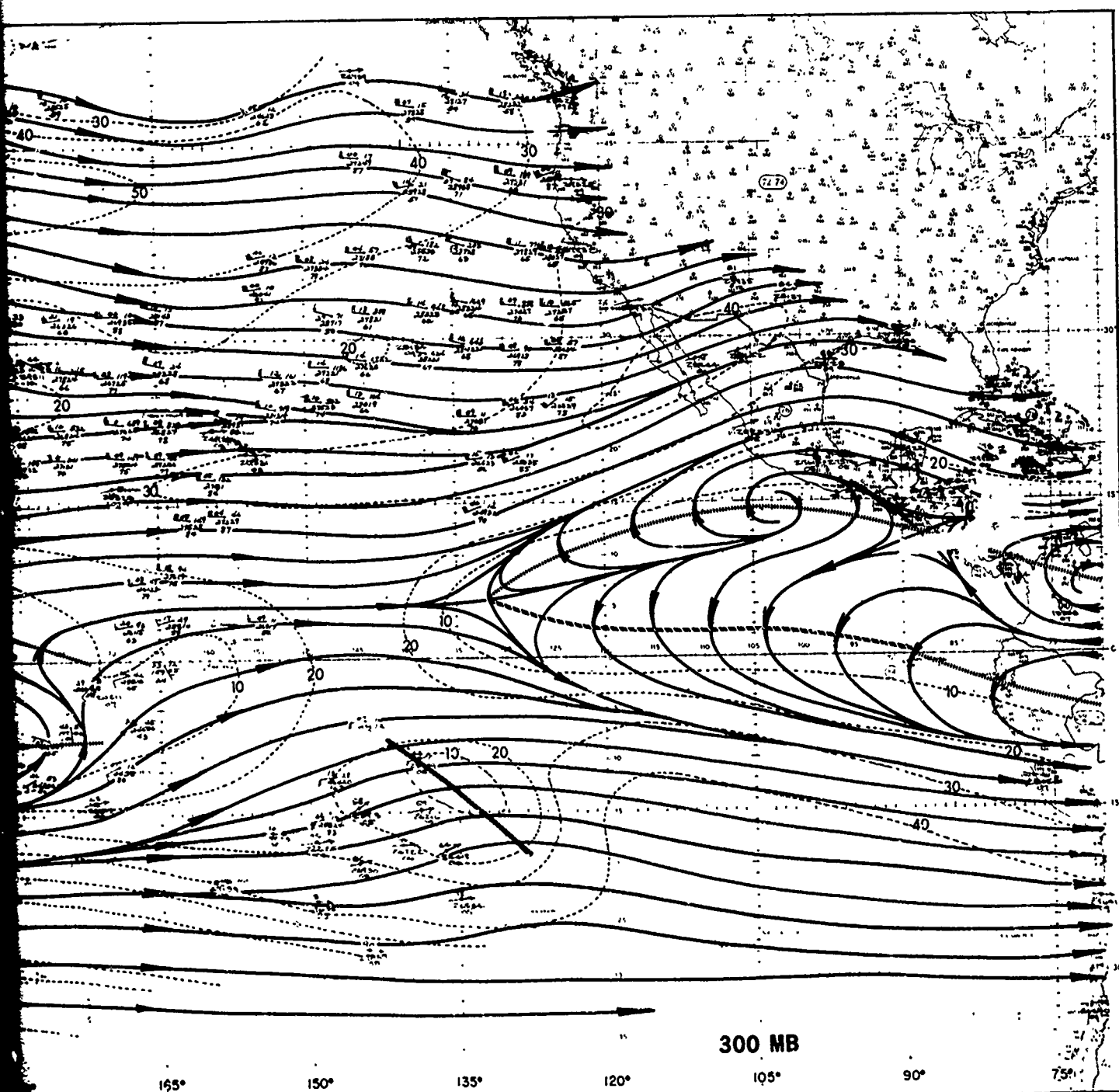
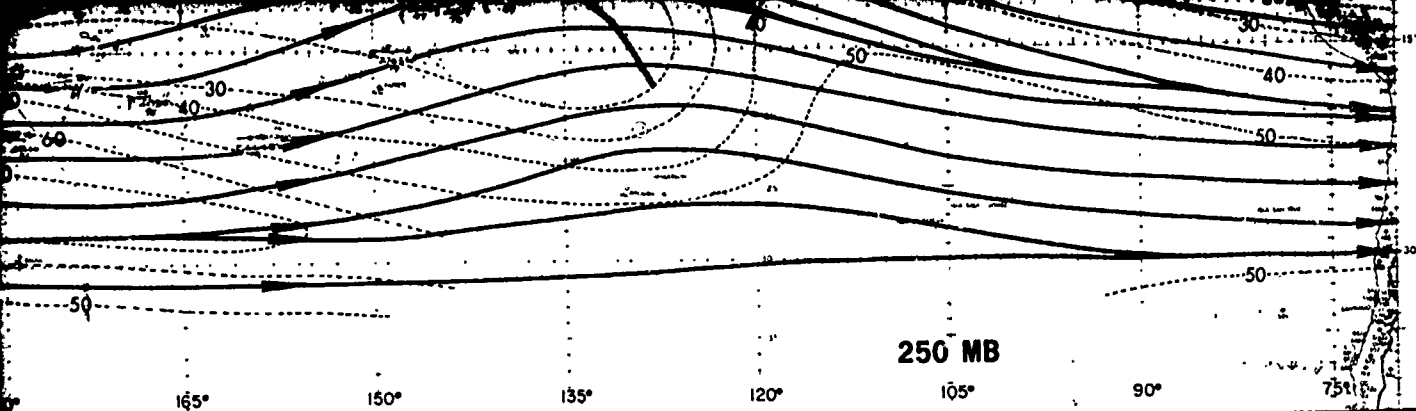
Rawins

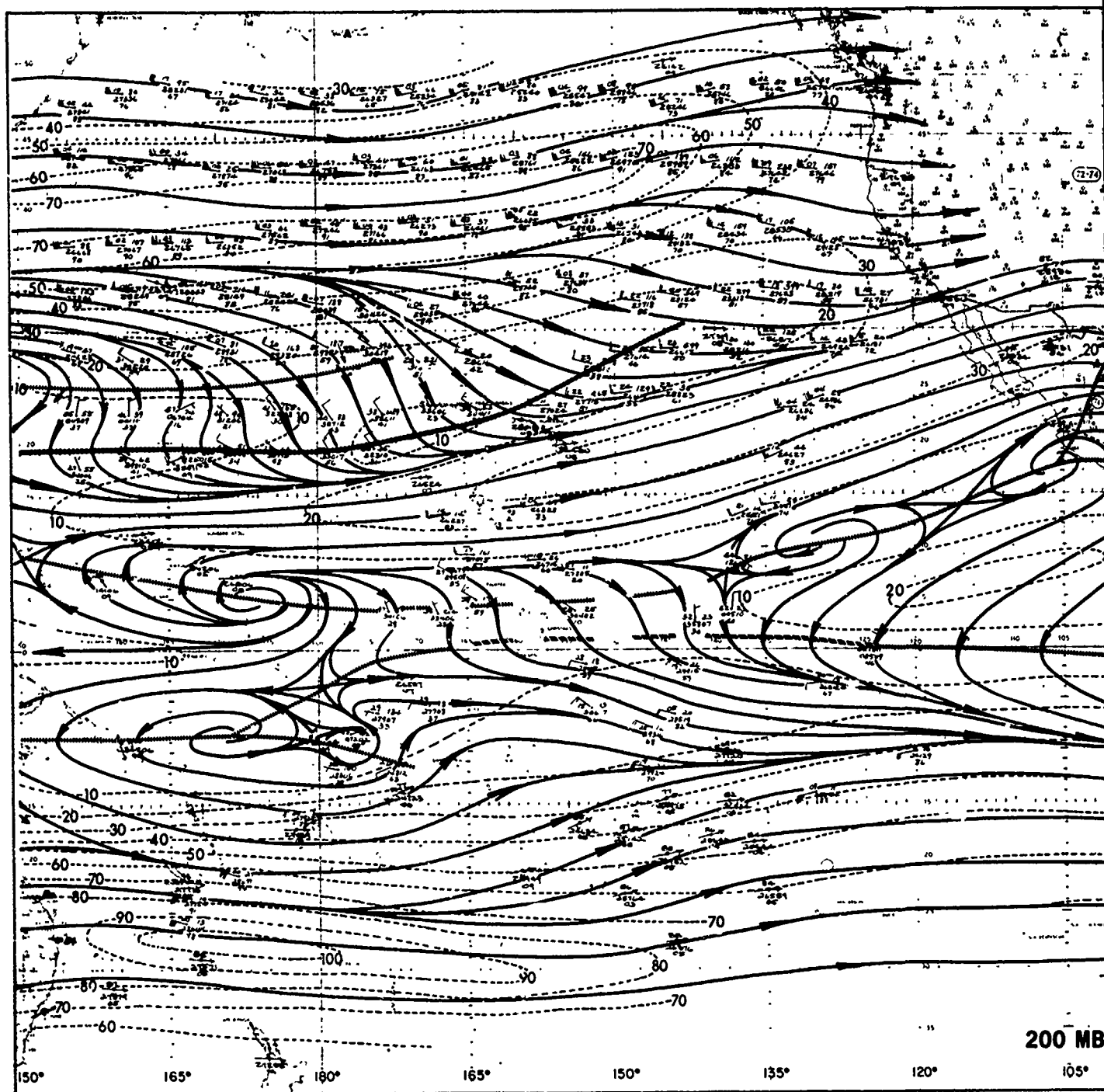
SS

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JUNE

Northern Hemisphere

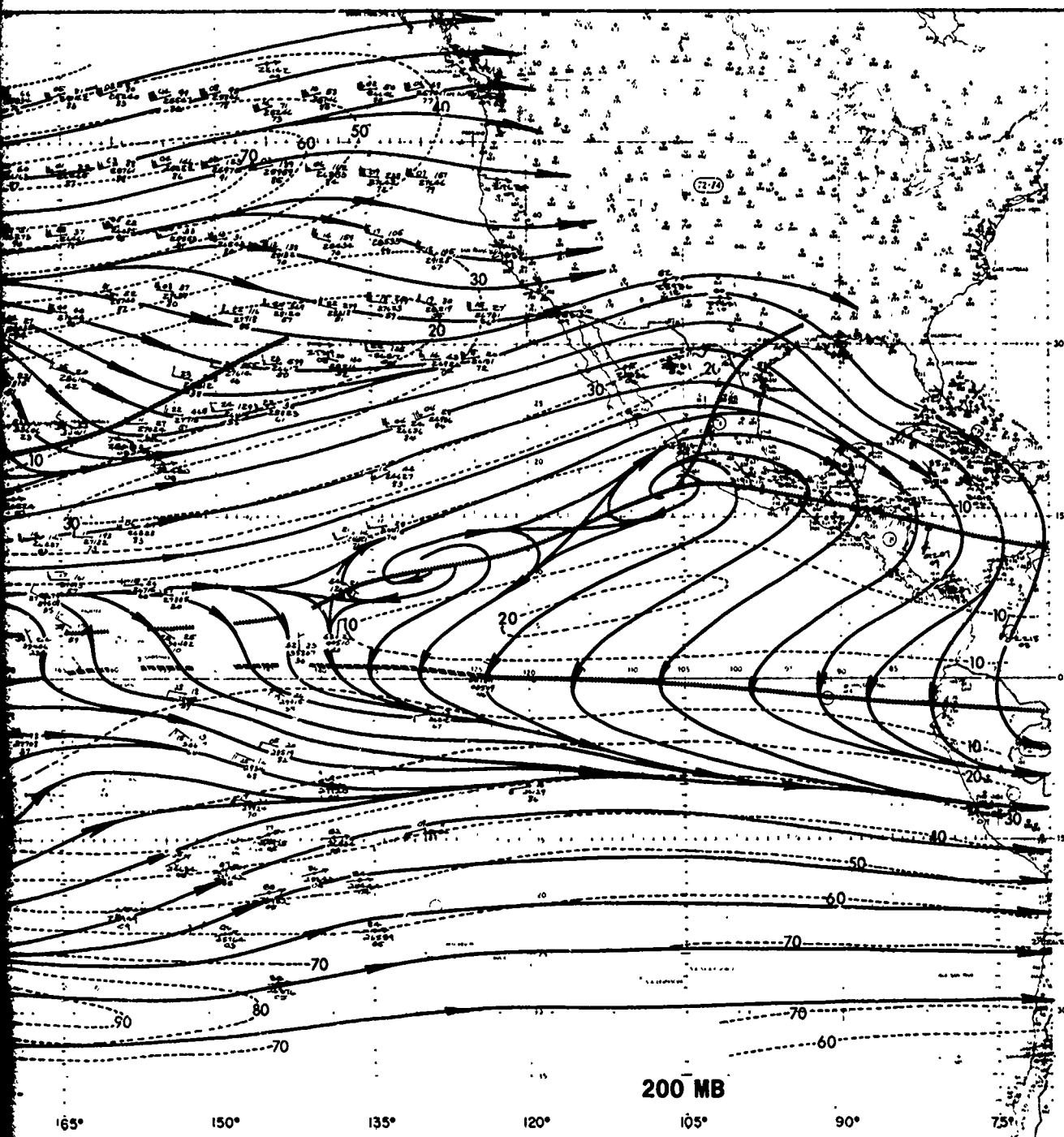
The core of the temperate westerlies remains near the April and May position of 38N at 155E; however, the decreasing speed trend has reversed, and the speeds have increased slightly from May. Perhaps of greater significance is the eastward extension of the maximum core. The 70 kt ribbon reaches beyond 150W, a marked change from May.

The subtropical westerlies in the eastern Pacific have continued

A belt of tropical easterly winds in the western Pacific north of 20N and the subtropical ridge.

Southern Hemisphere

The subtropical ridge has also been re-established



JUNE

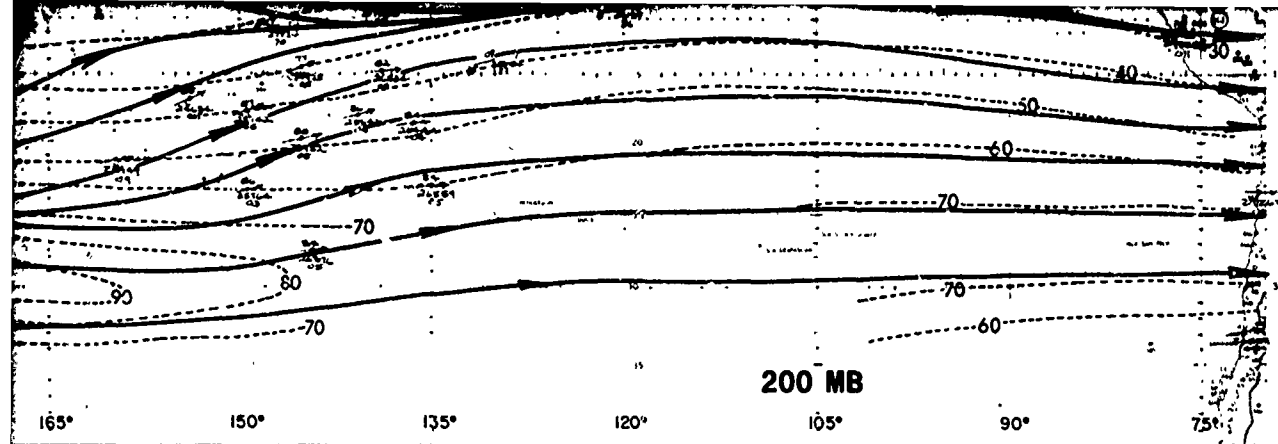
A belt of tropical easterlies has become established in the western Pacific north of 20N and westward of 170E between the MPT and the subtropical ridge.

Southern Hemisphere

The subtropical ridge has retreated southward to 9S at 155E and has also been re-established eastward beyond 180.

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Pacific have continued



JUNE

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y linked betw 170W

A belt of tropical easterlies has become established in the western Pacific north of 20N and westward of 170E between the MPT and the subtropical ridge.

Southern Hemisphere

The subtropical ridge has retreated southward to 9S at 155E and has also been re-established eastward beyond 180.


The TUTT has disappeared, and the temperate westerlies have increased considerably. The jet is located near 25S over eastern Australia; meager aircraft data indicates a 100-kt core east of Australia. The maximum westerlies remain near 25S over western South America and have increased.

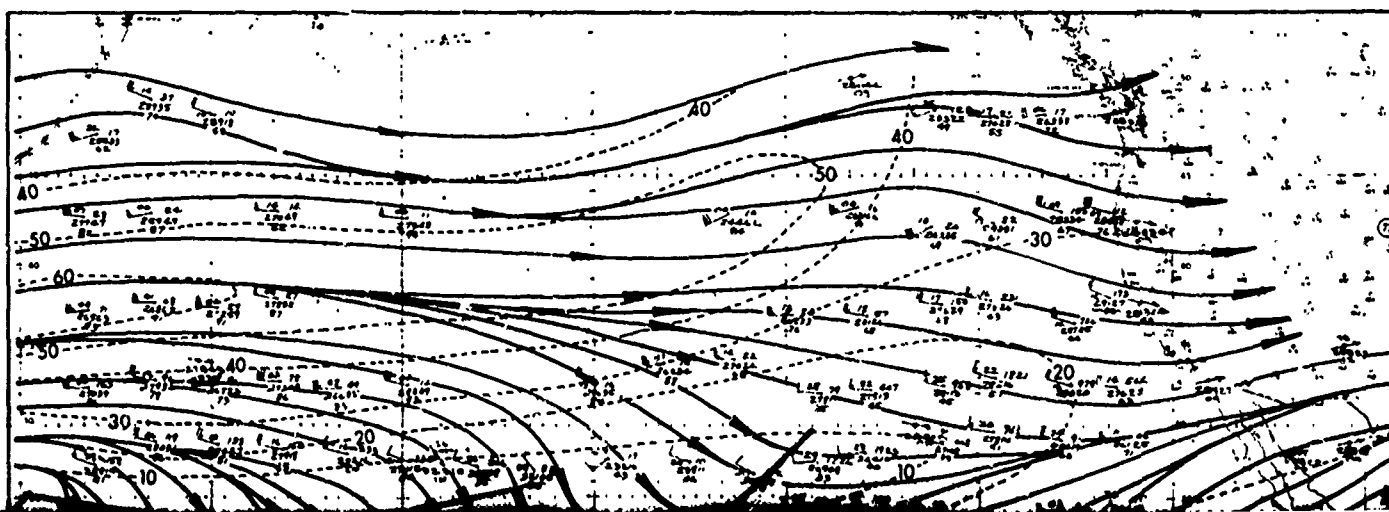
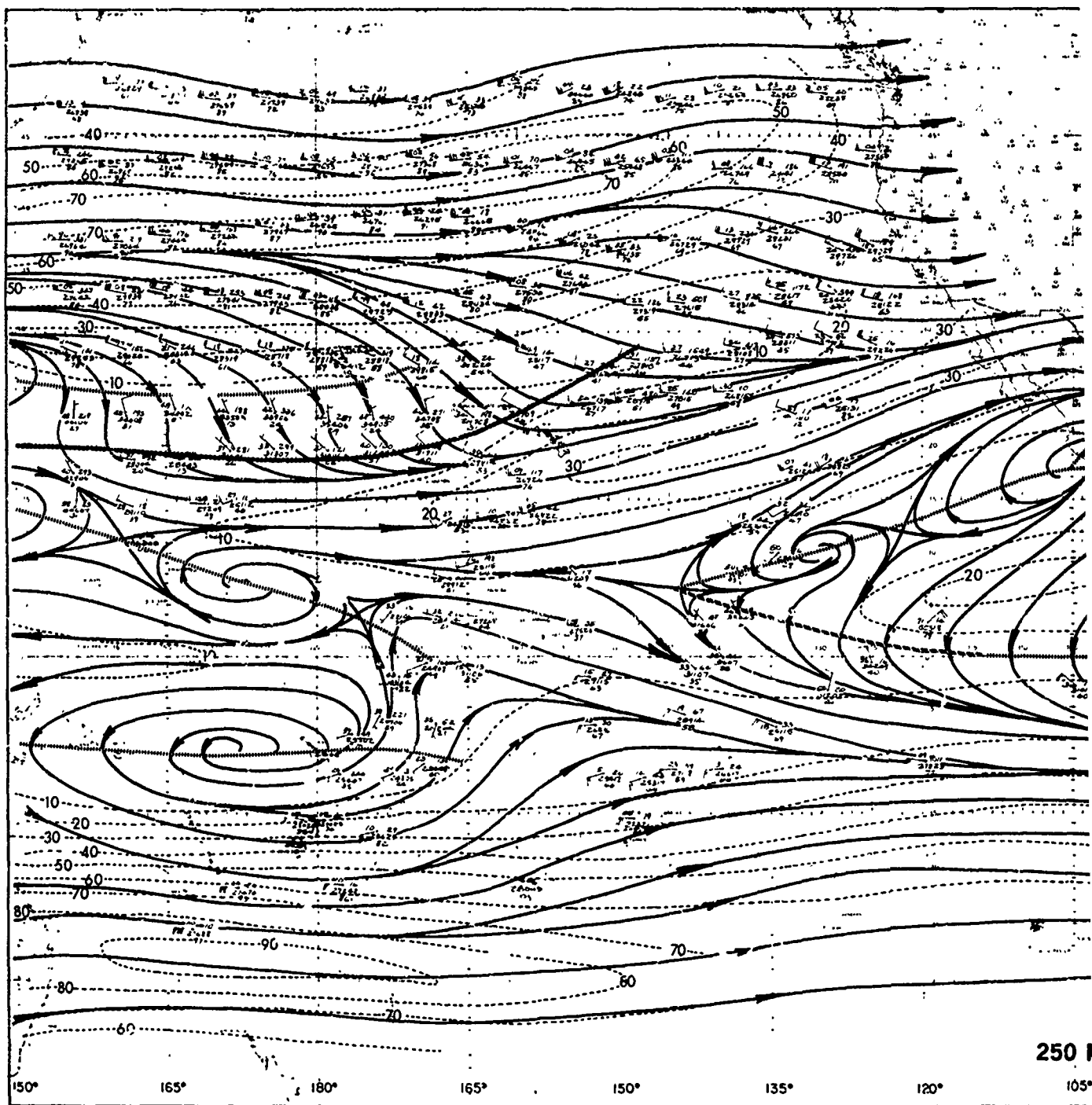
Equatorial Region

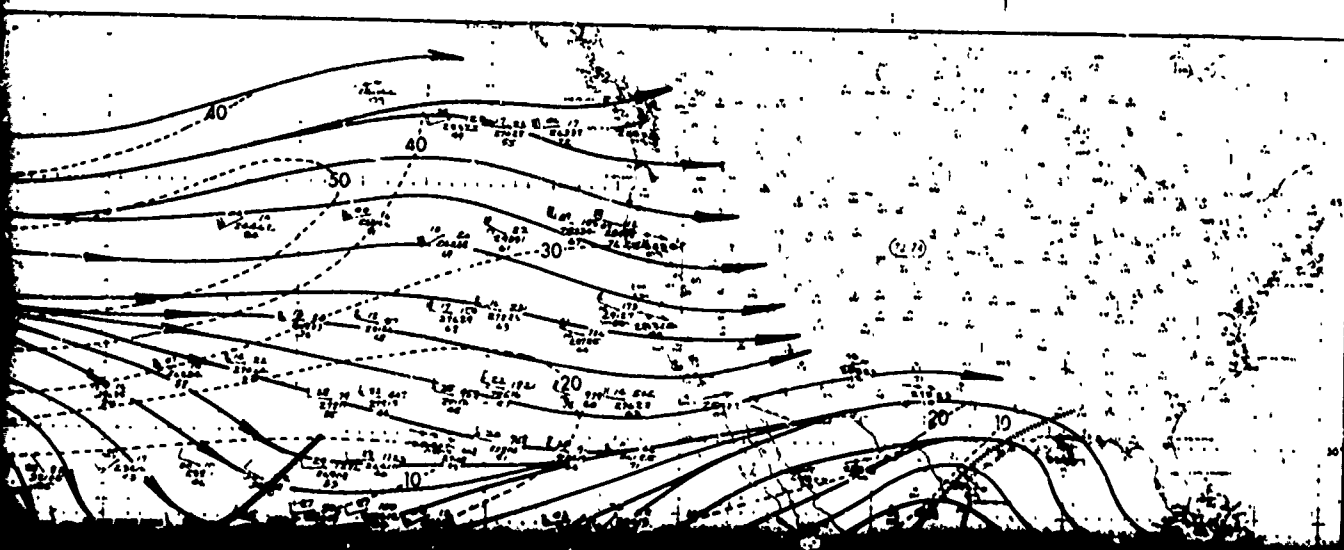
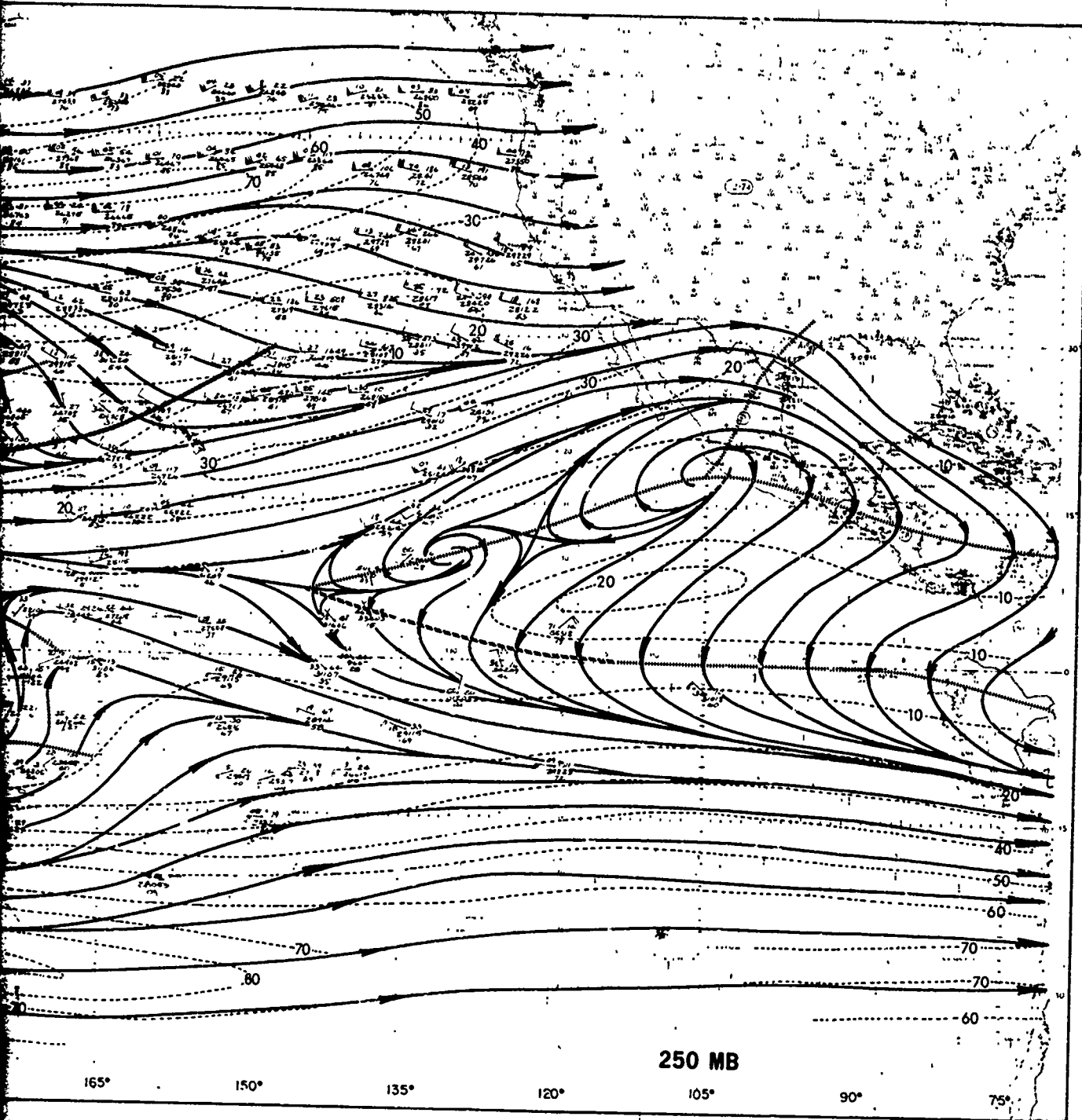
The belt of equatorial easterlies in the eastern Pacific has increased in area and speed as the ridge has moved northward. The easterlies are essentially confined to the Northern Hemisphere, and the buffer system is very near and parallel to the equator. The equatorial easterlies in the western Pacific have also expanded as the ridge in each hemisphere has moved poleward and expanded eastward. Equatorial easterlies have not yet become established between 170W and 140W.

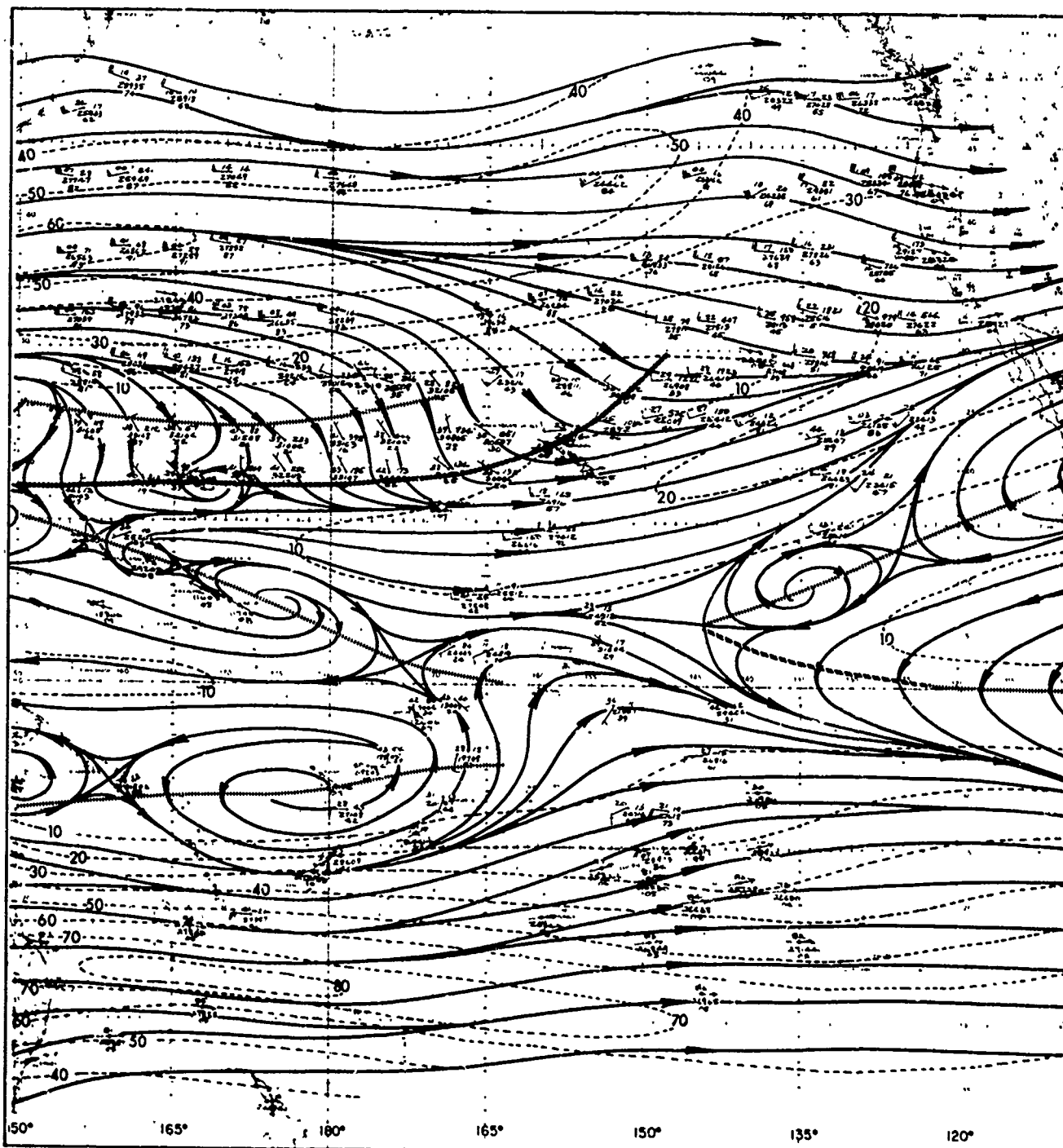
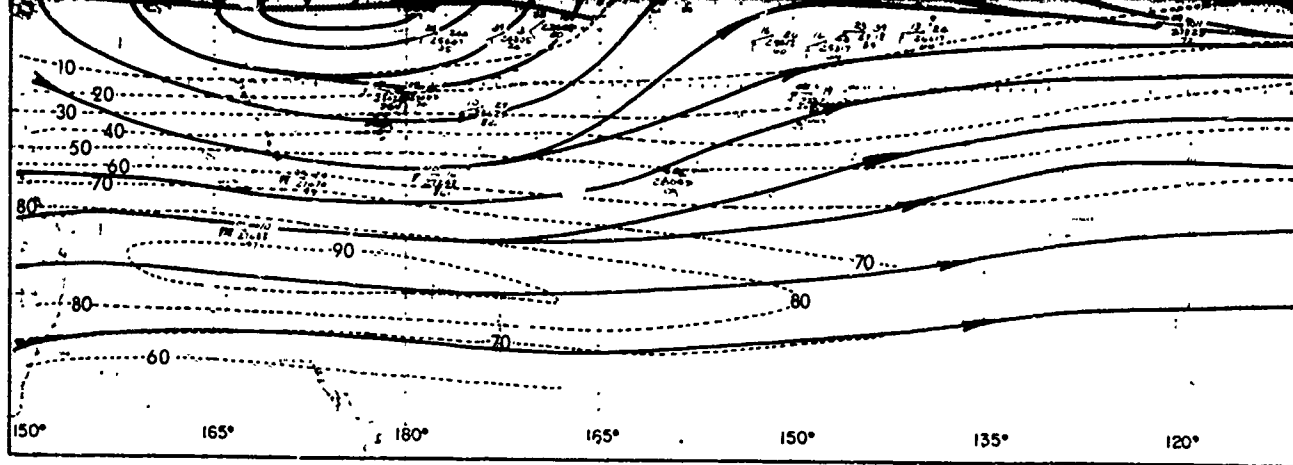
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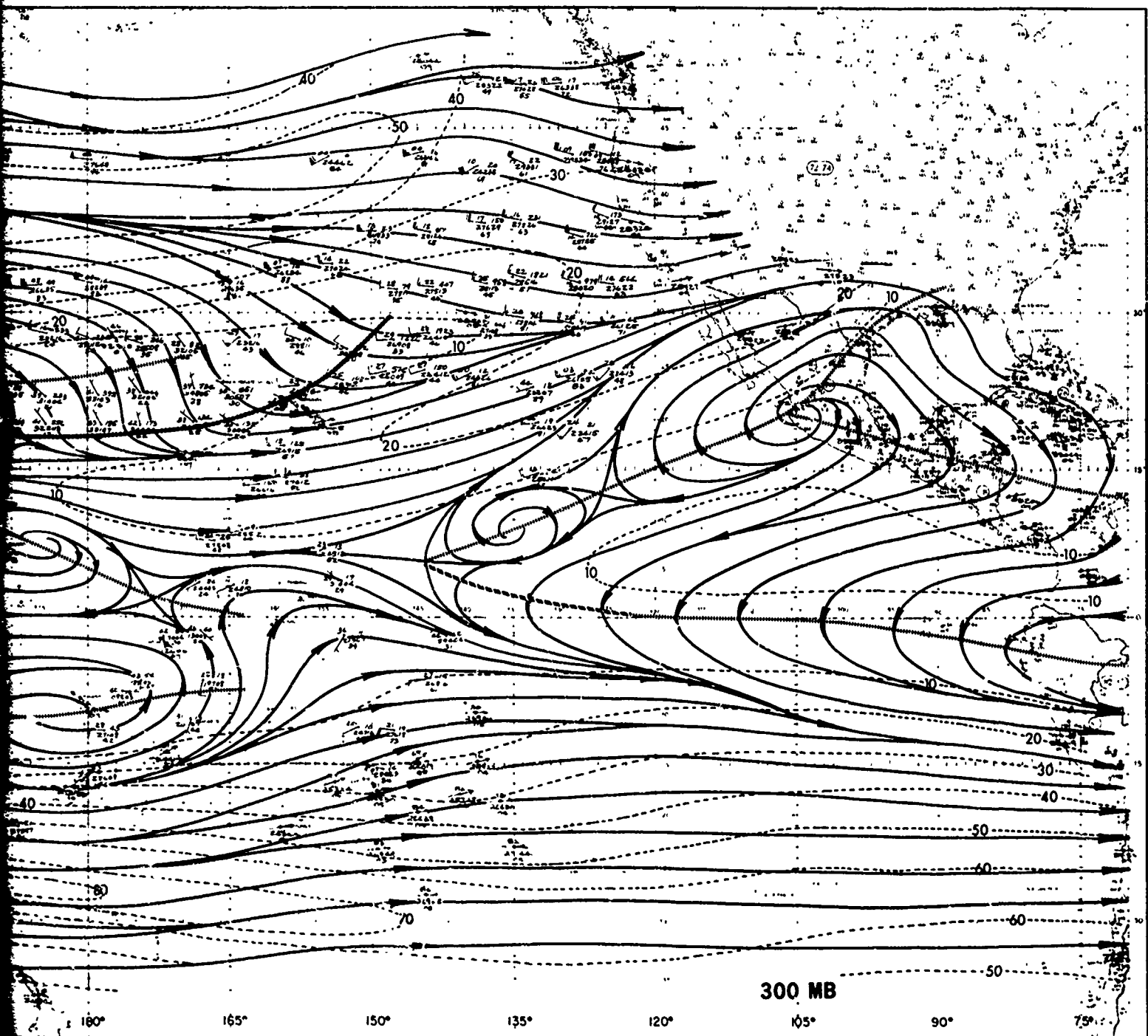
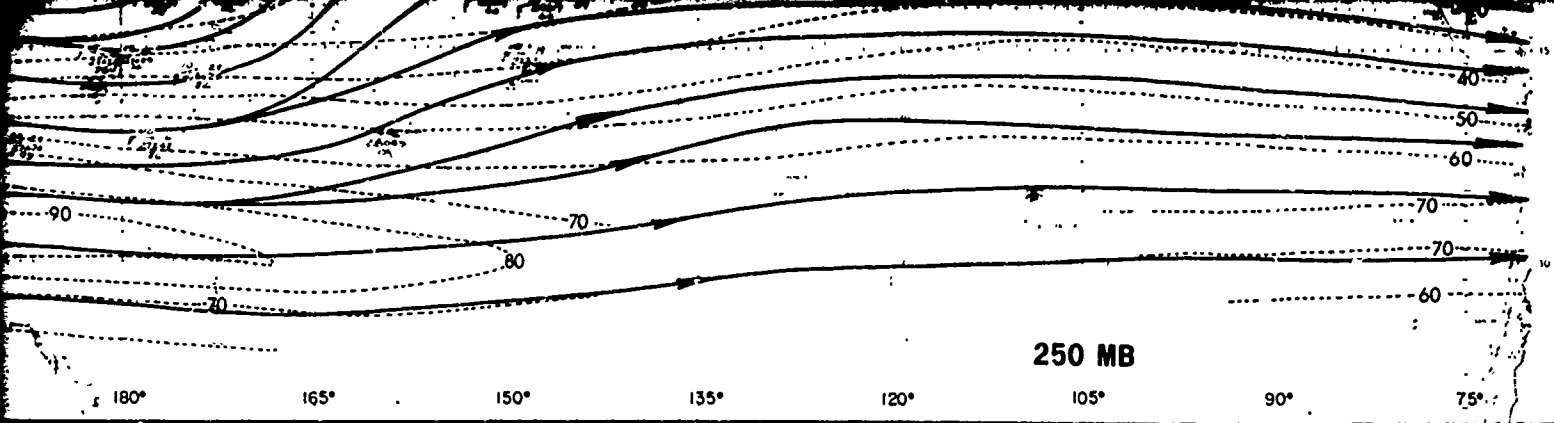
Rawins

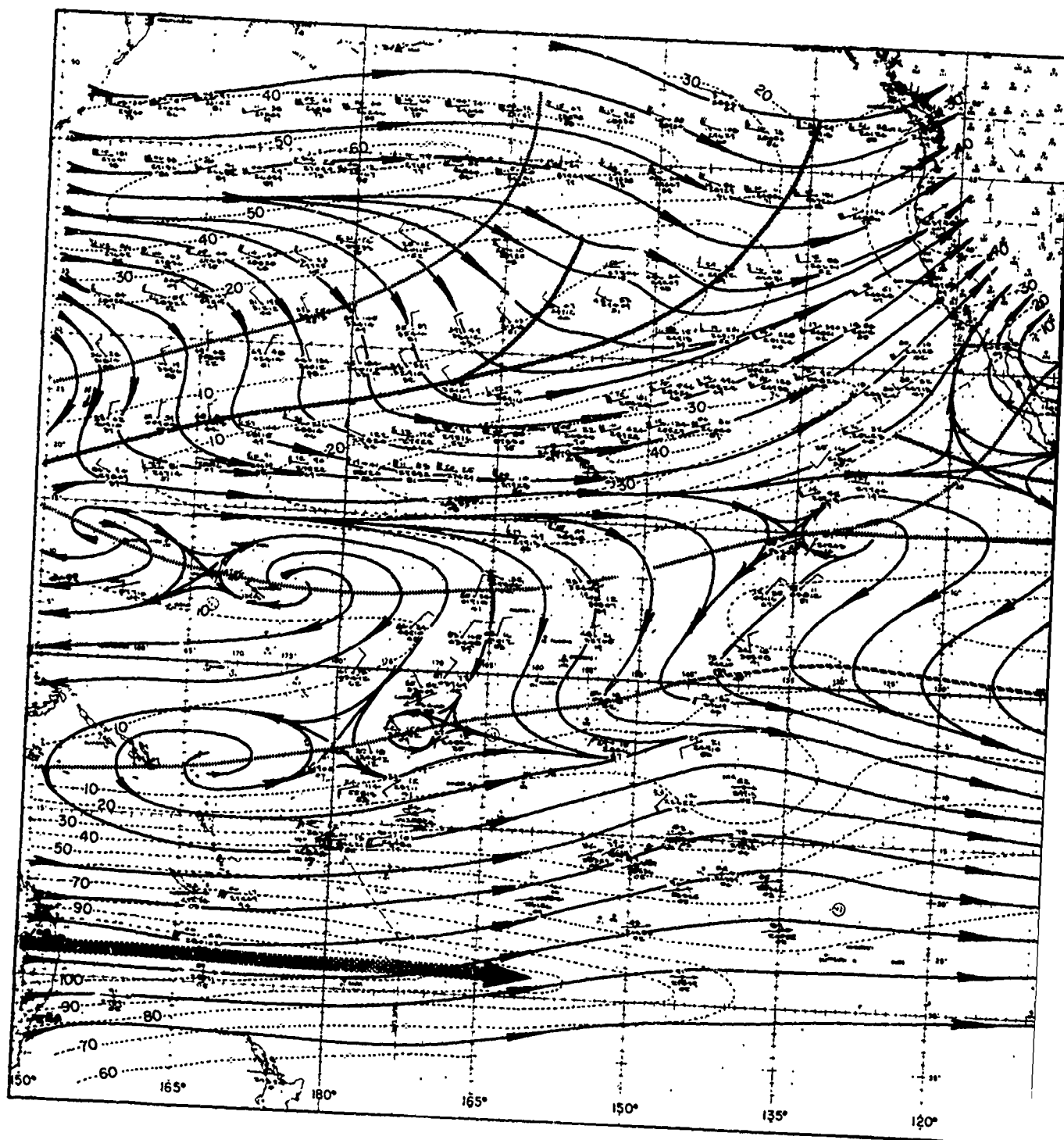
SS

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JULY

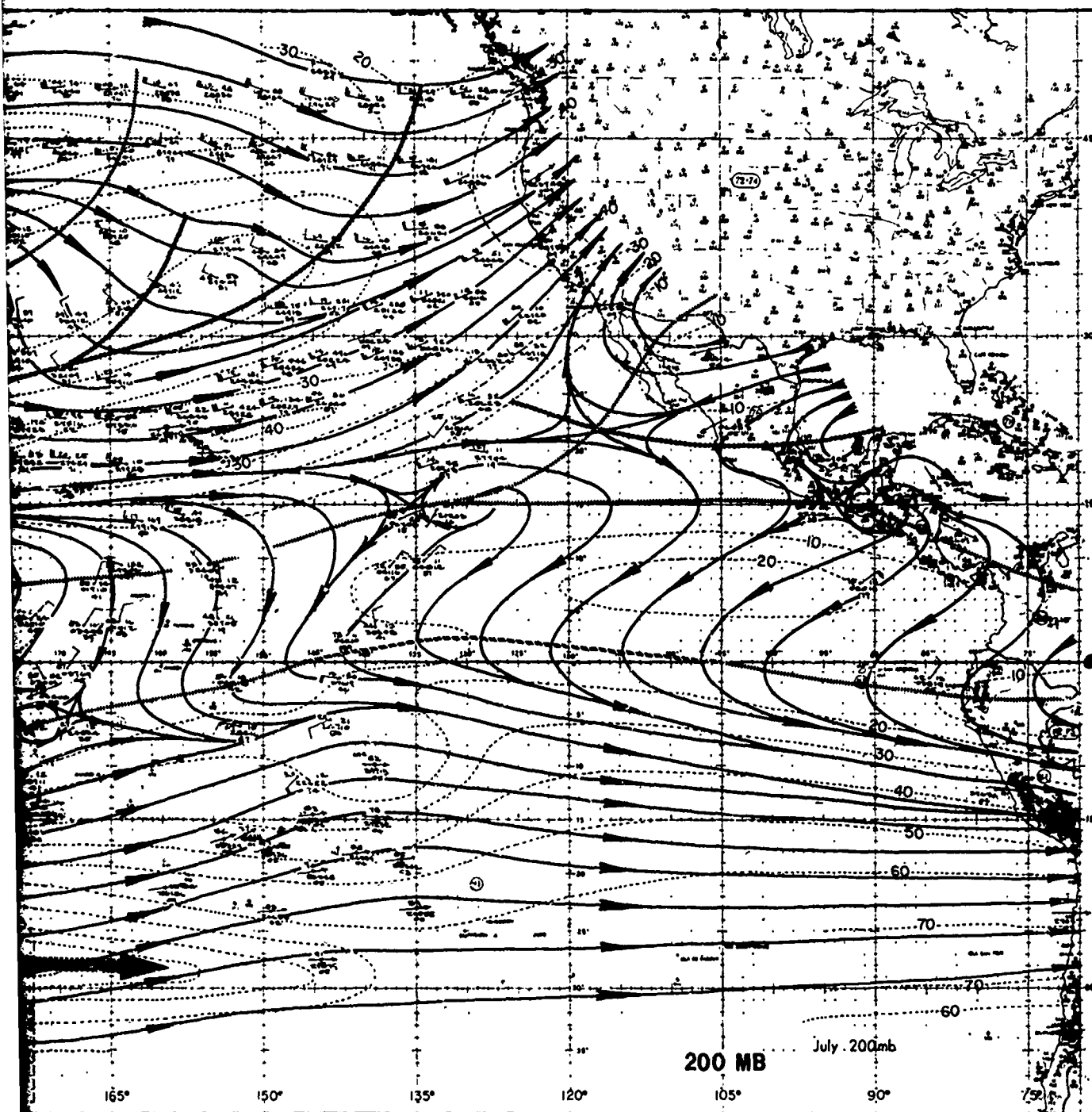
Northern Hemisphere

The subequatorial ridge has intensified and is essentially continuous across the area; however, a weakness remains in the ridge between 160W and 150W. The western portion has moved northward to near 12N at 155E. Flow in the extreme eastern Pacific has been complicated by formation of a ridge over the southern United States and appearance of the tropical upper-tropospheric trough across Central America near 20N.

The core of subtr maximum speeds of near

Southern Hemisphere

The subtropical ridge east of 180. The (cyclonic) between 145



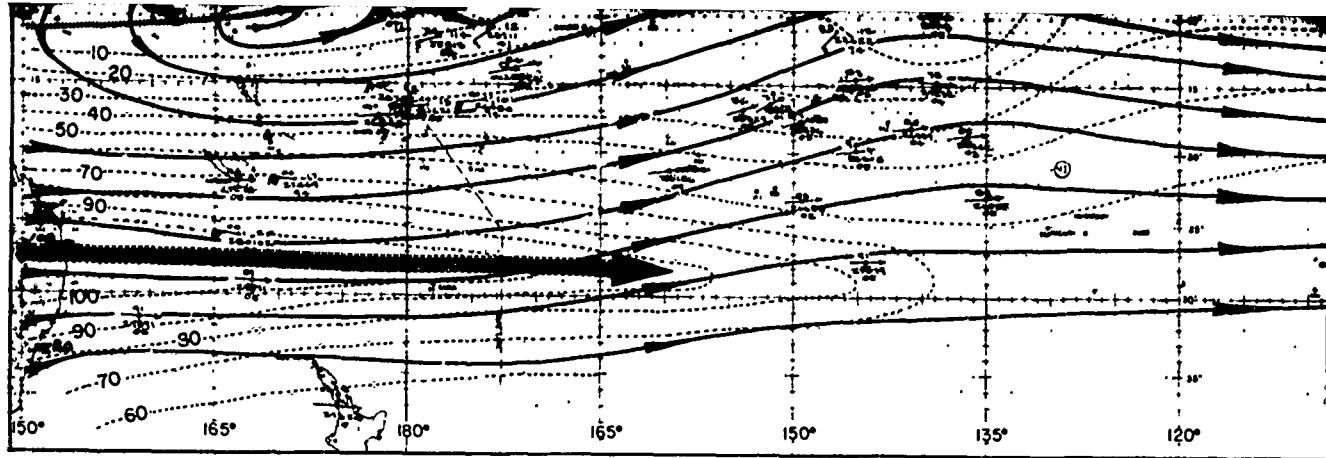
JULY

The core of subtropical westerlies has moved northward with maximum speeds of near 40 kt through the Hawaiian Islands.

Southern Hemisphere

The subtropical ridge remains near 9S at 155E. It joins the buffer ridge east of 180. The buffer system lies north of the equator (cyclonic) between 145W and 105W.

The temperature has increased to greater than 100 kt and is



JULY

Northern Hemisphere

The subequatorial ridge has intensified and is essentially continuous across the area; however, a weakness remains in the ridge between 160W and 150W. The western portion has moved northward to near 12N at 155E. Flow in the extreme eastern Pacific has been complicated by formation of a ridge over the southern United States and appearance of the tropical upper-tropospheric trough across Central America near 20N.

The tropical upper-tropospheric trough in the Pacific has intensified and moved northward. It is a continuous feature from 20N, 155E northeastward to 50N, 135W.

The subtropical ridge in the northwestern Pacific is more pronounced than in June and extends from near 26N, 155E northeastward.

The temperate westerlies have shrunk considerably, and the core speed has decreased to near 60 kt. The greatest speeds are near 45N, 180. Previous to July this current comprised an eastward extension of stronger flow across Japan.

The core of subtr
maximum speeds of near

Southern Hemisphere

The subtropical r
ridge east of 180. Th
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The temperate jet
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a winter trough in the
South America have inc
near 25S.

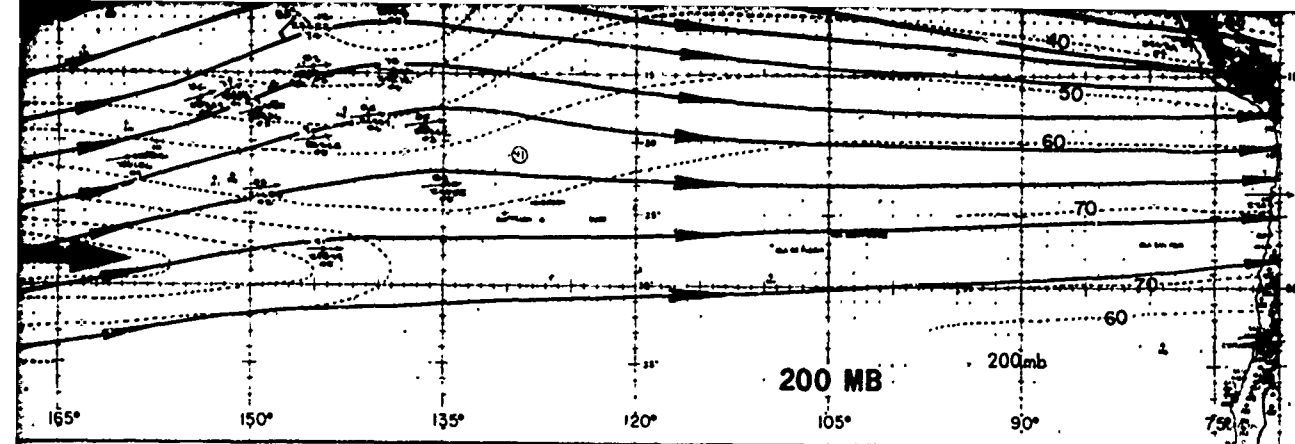
Equatorial Region

The equatorial ea
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equator.

PIREP Winds

EE nnnn
dddfff
SS

EE	-percentage of winds with an east component
nnnn	-number of observations
ddd	-mean resultant wind direction
fff	-mean resultant wind speed in knots (flag 50 knots, long barb = 10 knots, short barb = 5 knots)
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JULY

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Pacific has been com-
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feature from 20N, 155E

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The core of subtropical westerlies has moved northward with maximum speeds of near 40 kt through the Hawaiian Islands.

Southern Hemisphere

The subtropical ridge remains near 9S at 155E. It joins the buffer ridge east of 180. The buffer system lies north of the equator (cyclonic) between 145W and 105W.


The temperate jet has increased to greater than 100 kt and is centered over eastern Australia near 28S. Speeds over French Polynesia have decreased, probably indicating the formation or intensification of a winter trough in the westerlies near 135W. Speeds over western South America have increased slightly from June; the core remains near 25S.

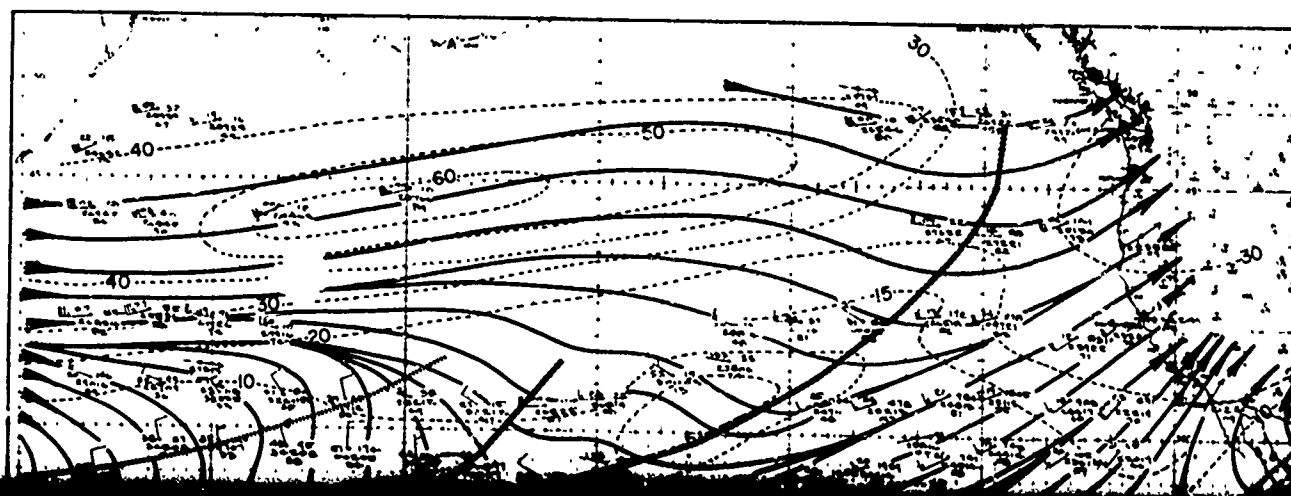
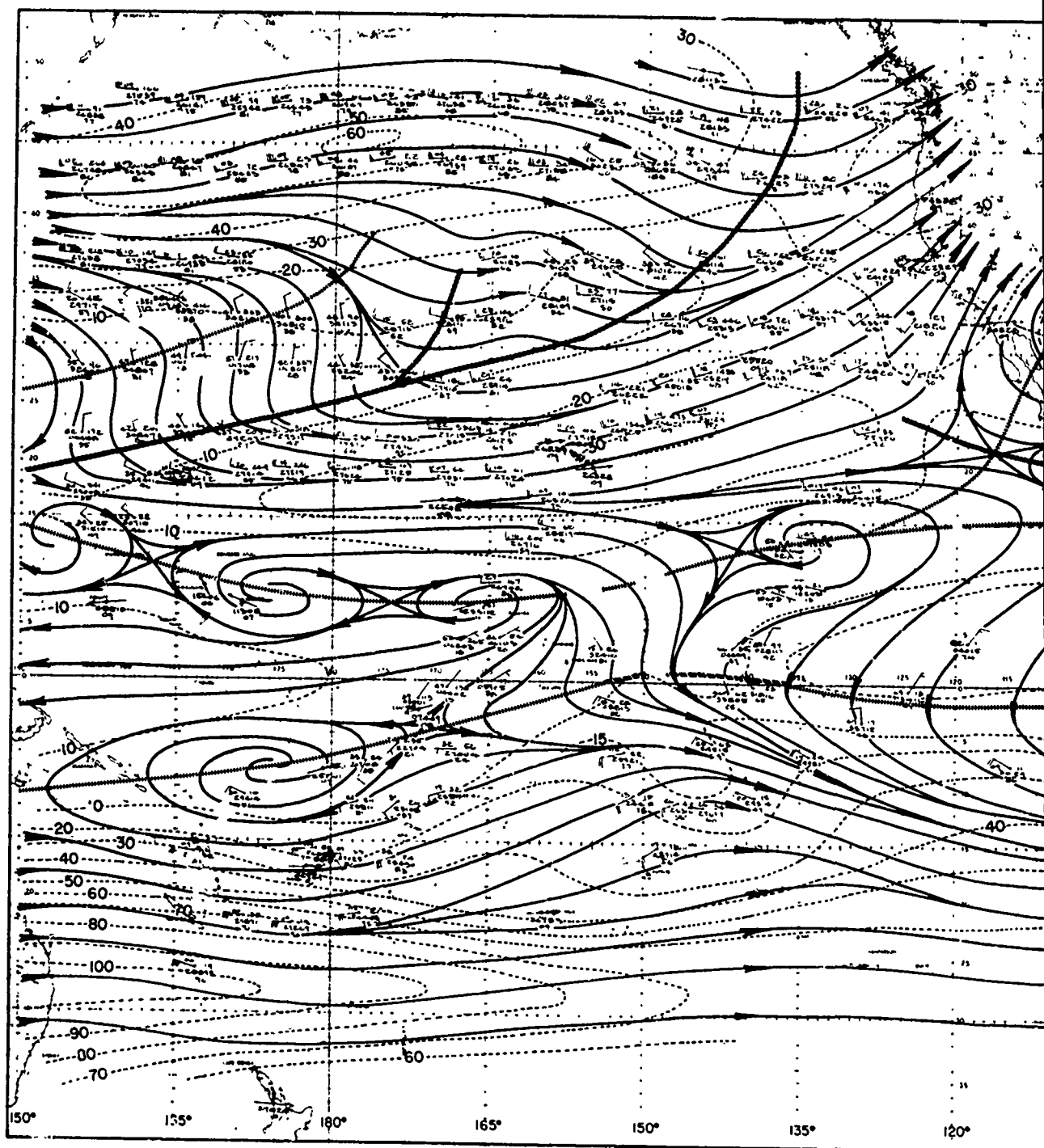
Equatorial Region

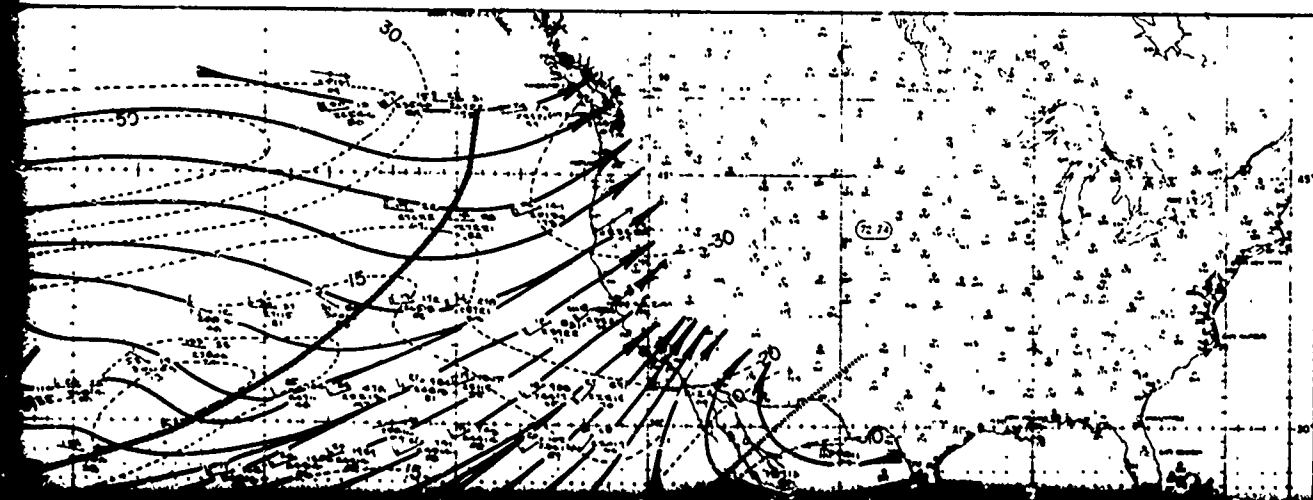
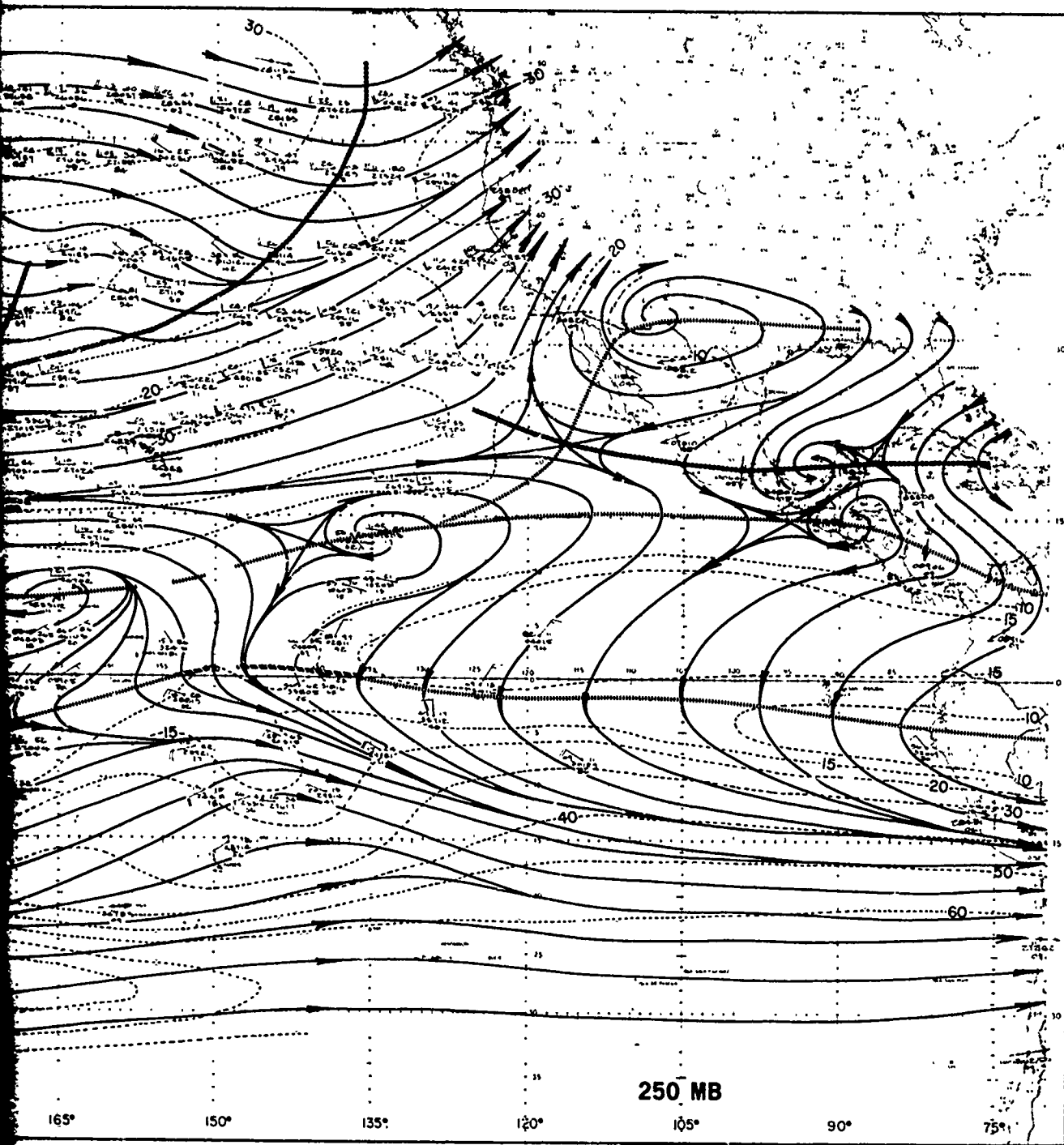
The equatorial easterlies have expanded in the Northern Hemisphere as the ridge has intensified and moved northward. Westerlies remain between 145W and 105W where the buffer system is north of the equator.

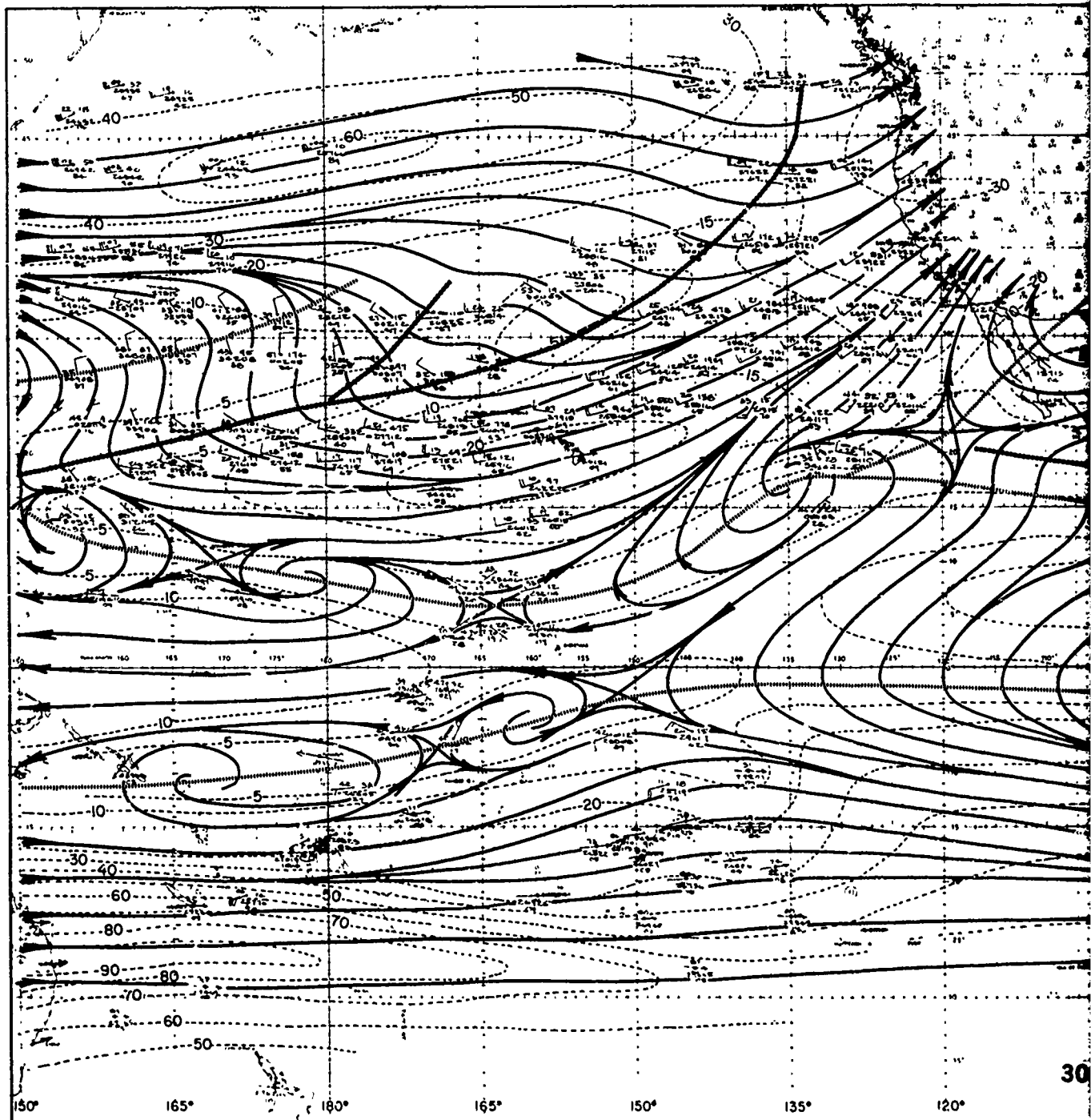
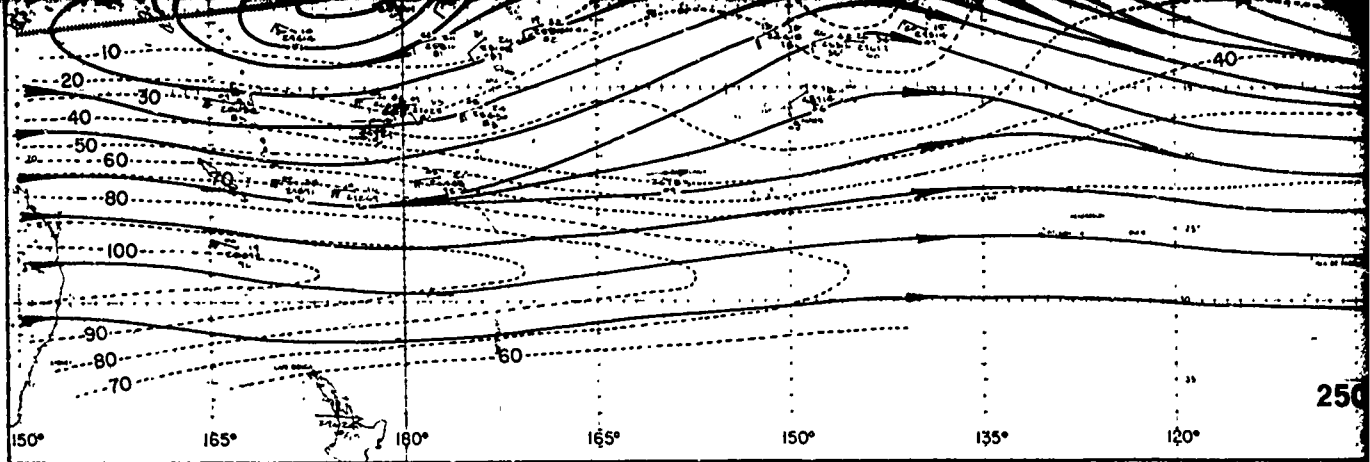
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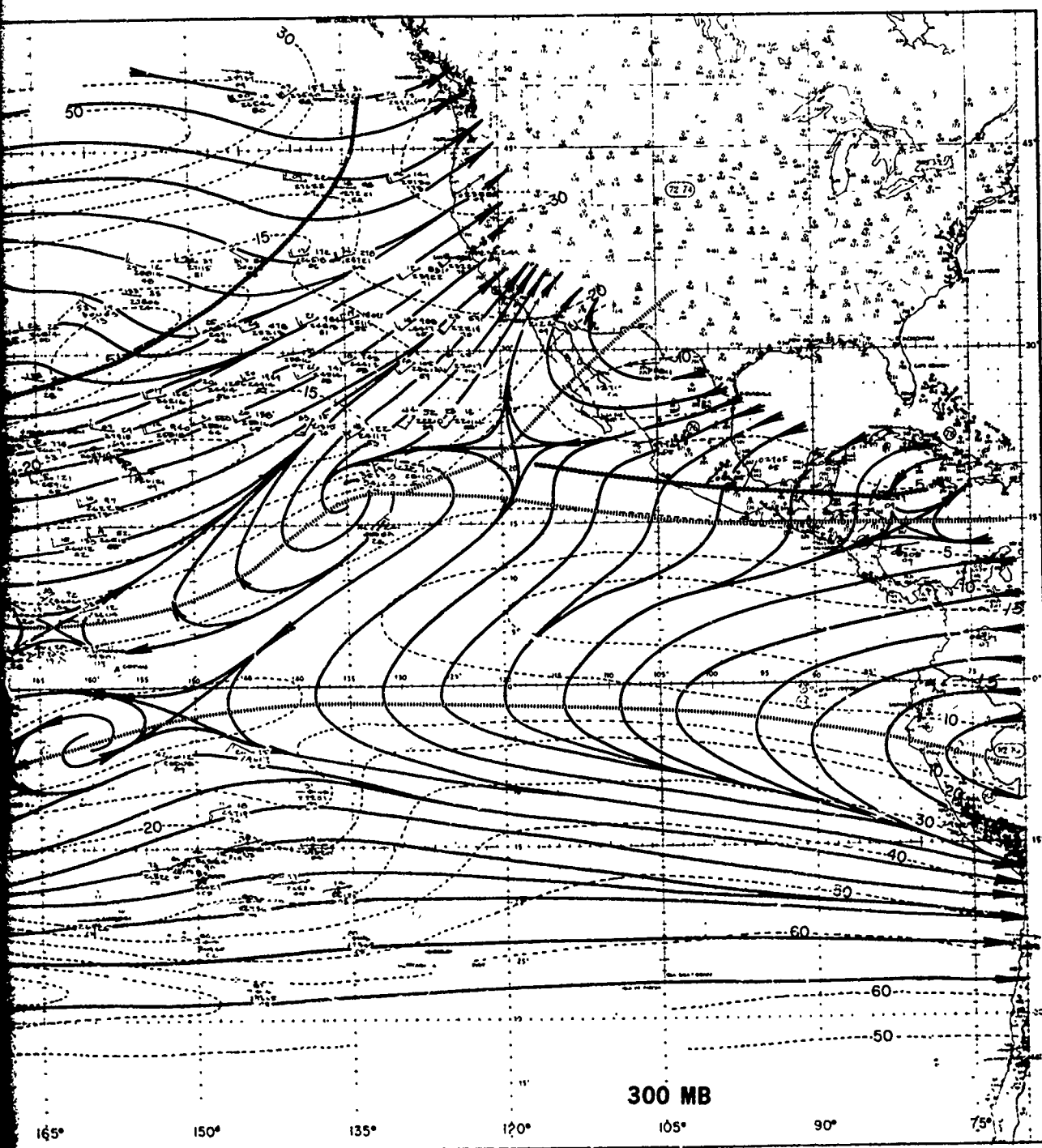
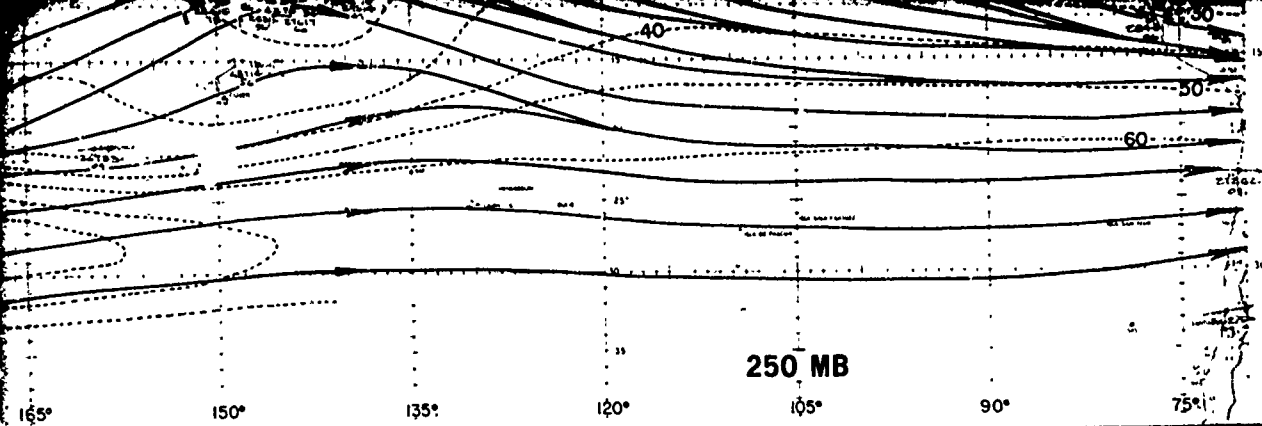
Rawins

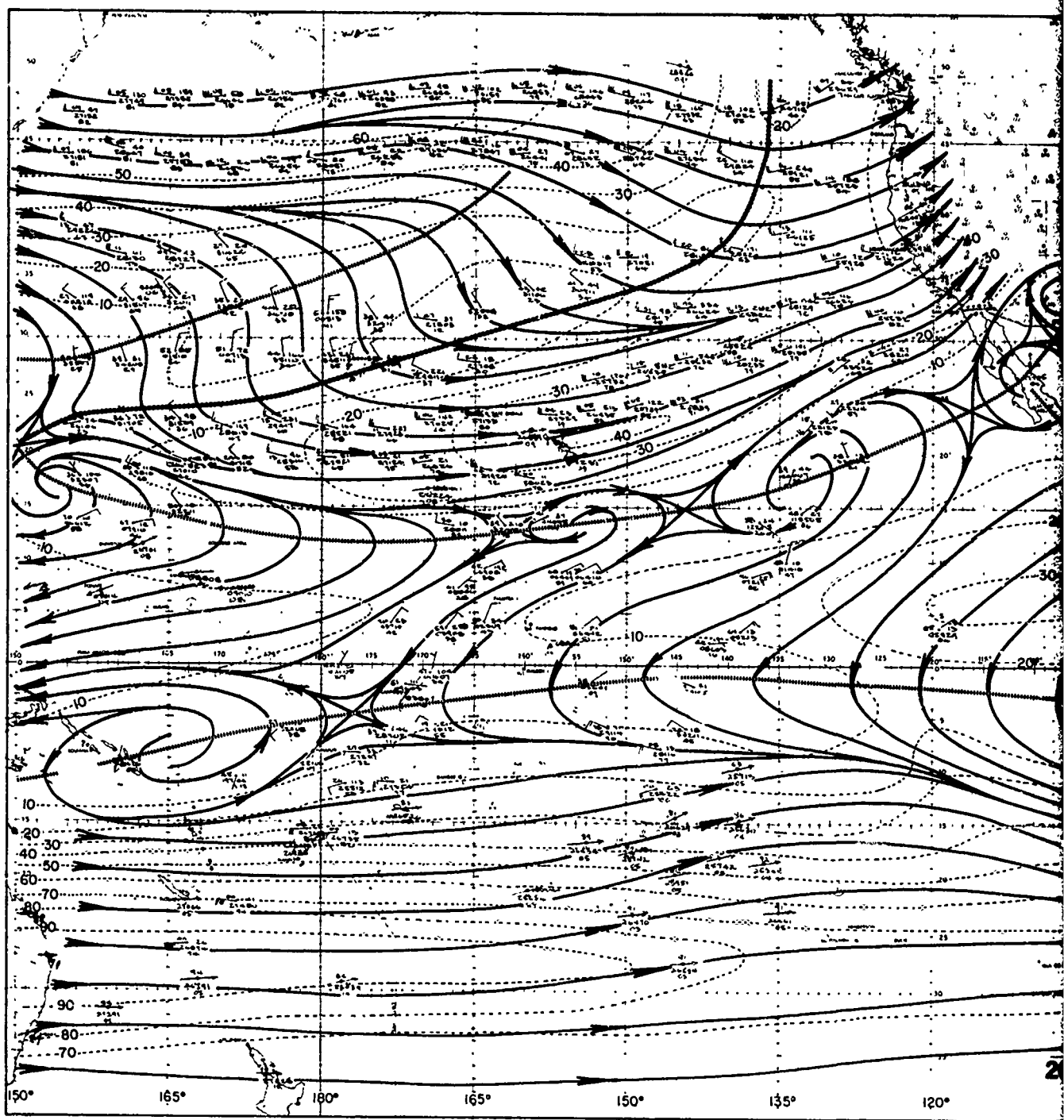
SS

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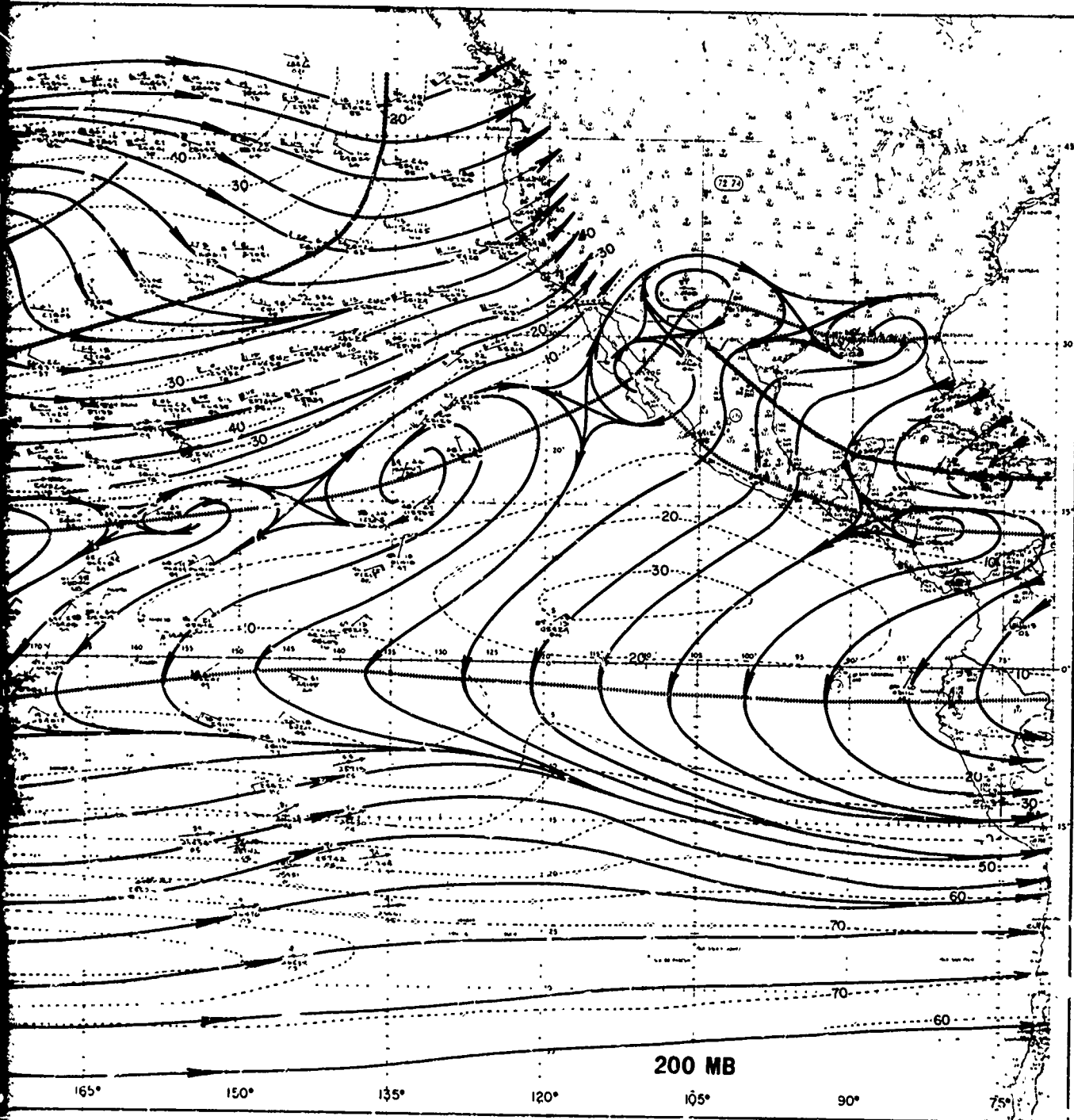


AUGUST

Northern Hemisphere

All systems have moved northward. The subequatorial ridge intensified and is continuous from the western Pacific to South America. The circulation patterns and major current speeds changed little from July.

Southern Hemisphere

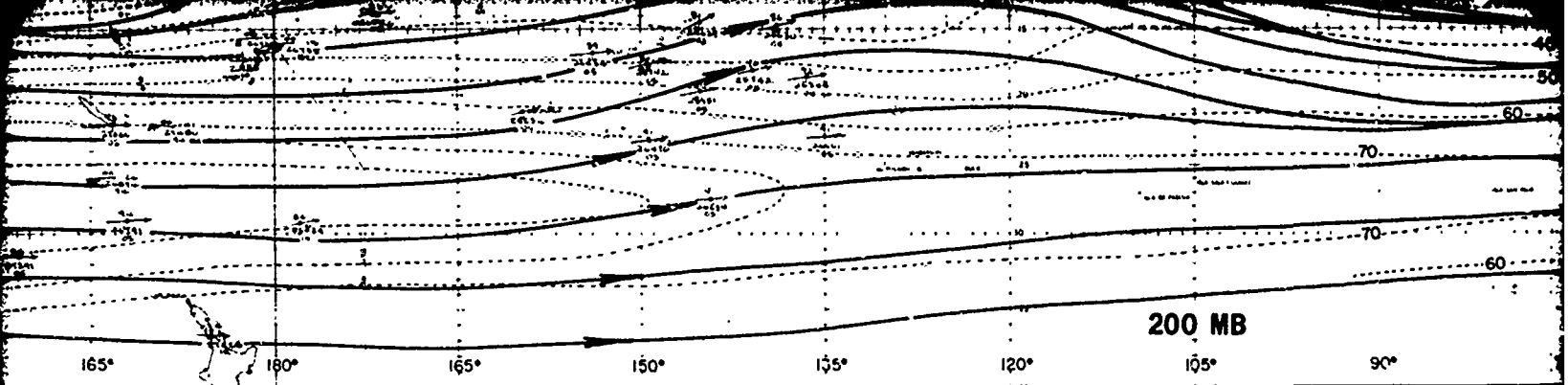


AUGUST

North Hemisphere

All systems have moved northward. The subequatorial ridge has intensified and is continuous from the western Pacific to South America. The circulation patterns and major current speeds have changed little from July.

South Hemisphere



AUGUST

Northern Hemisphere

All systems have moved northward. The subequatorial ridge has intensified and is continuous from the western Pacific to South America. The circulation patterns and major current speeds have changed little from July.

Southern Hemisphere


The subtropical ridge is near 10S at 155E and links with the buffer system which lies south of the equator across the entire eastern Pacific.

The temperate jet position and intensity have changed little from July. The trough in the westerlies has moved eastward of 135W.

Equatorial Region


This is the first month in the year that easterly winds are found on the equator at all longitudes. The speed of the northeast current outflowing from the eastern Pacific low-level monsoon has increased to near 30 kt.

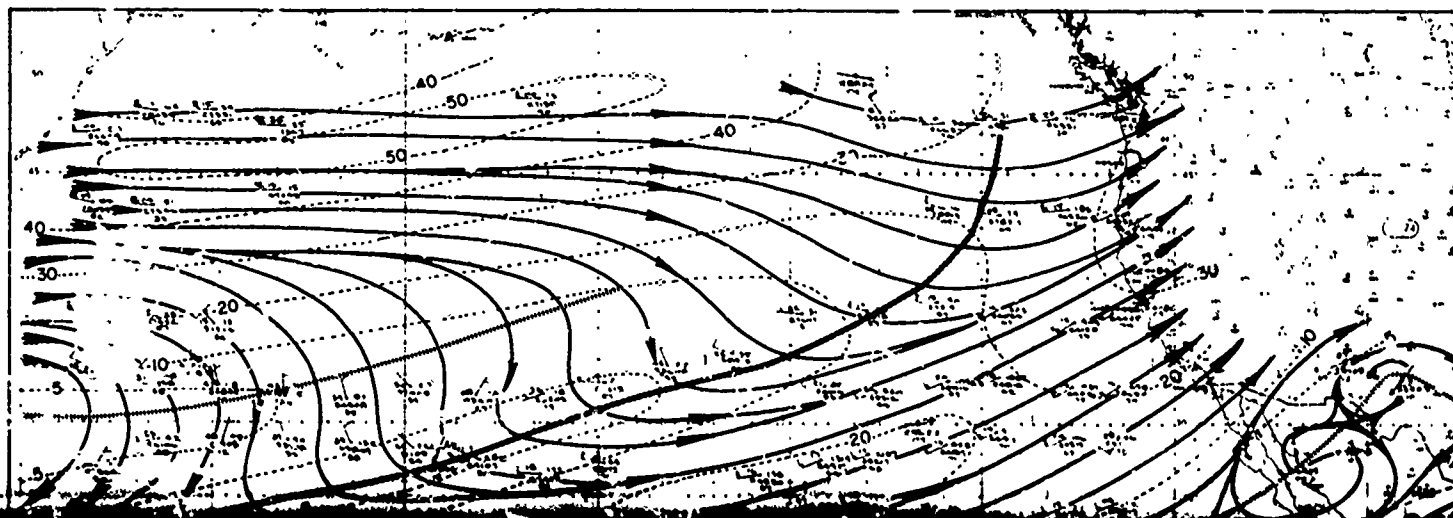
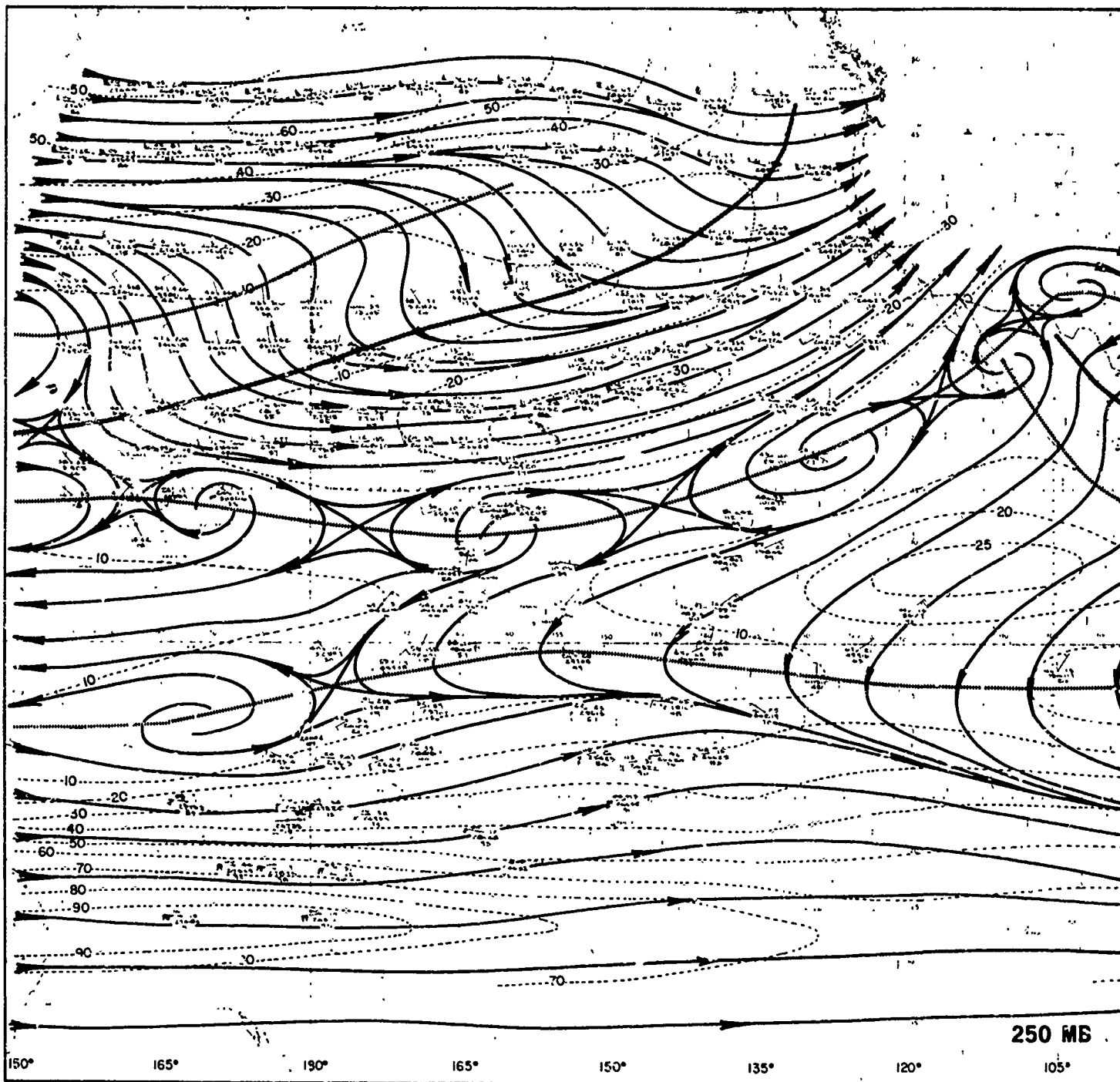
PIREP Winds

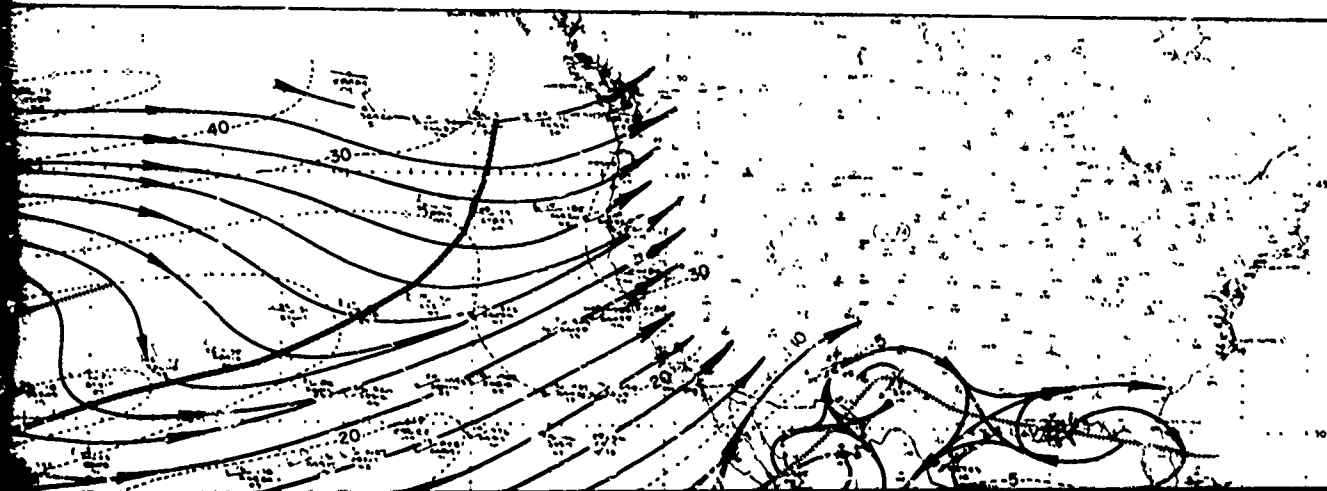
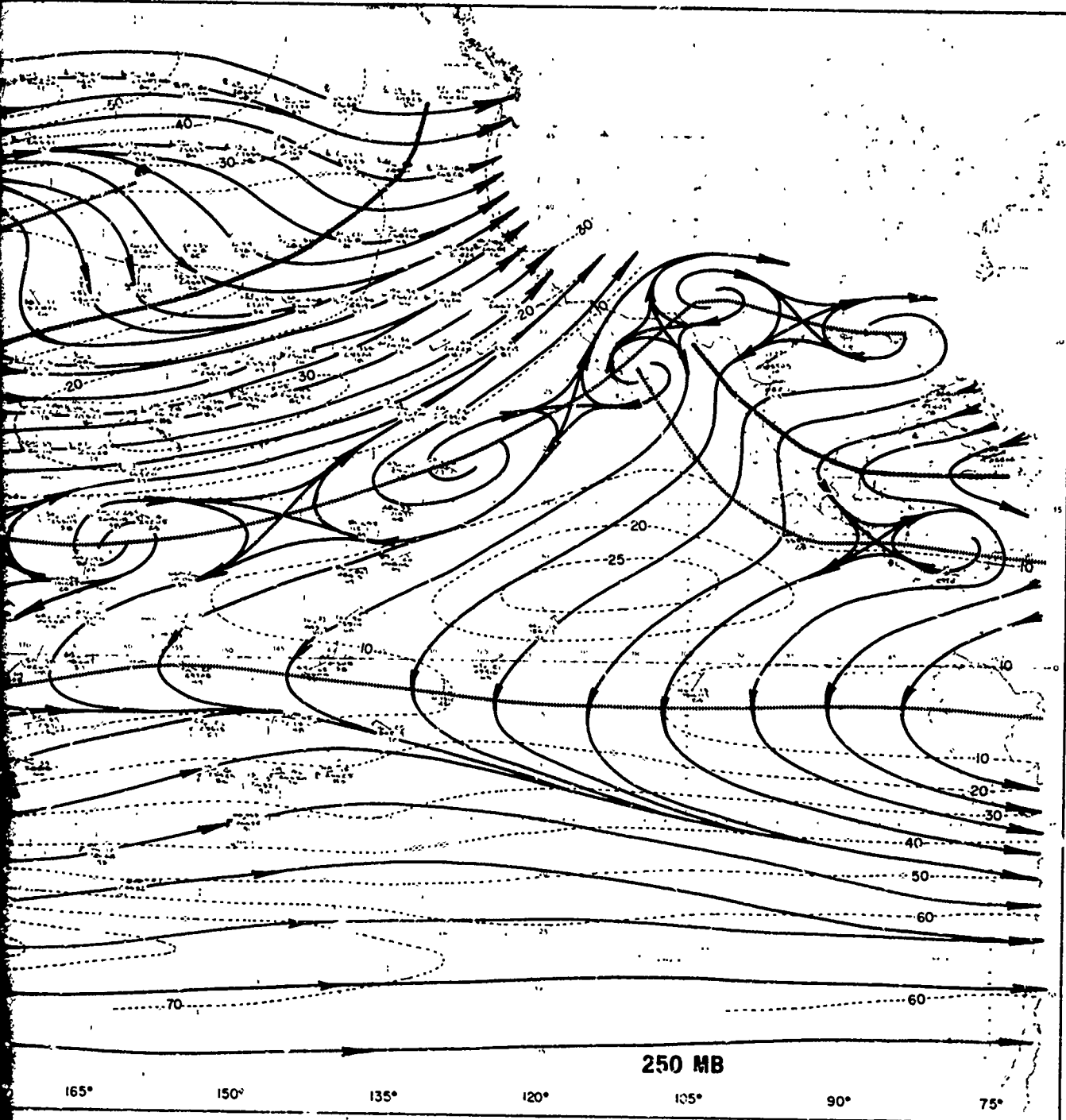
EE nnnn

 dddfff
 SS

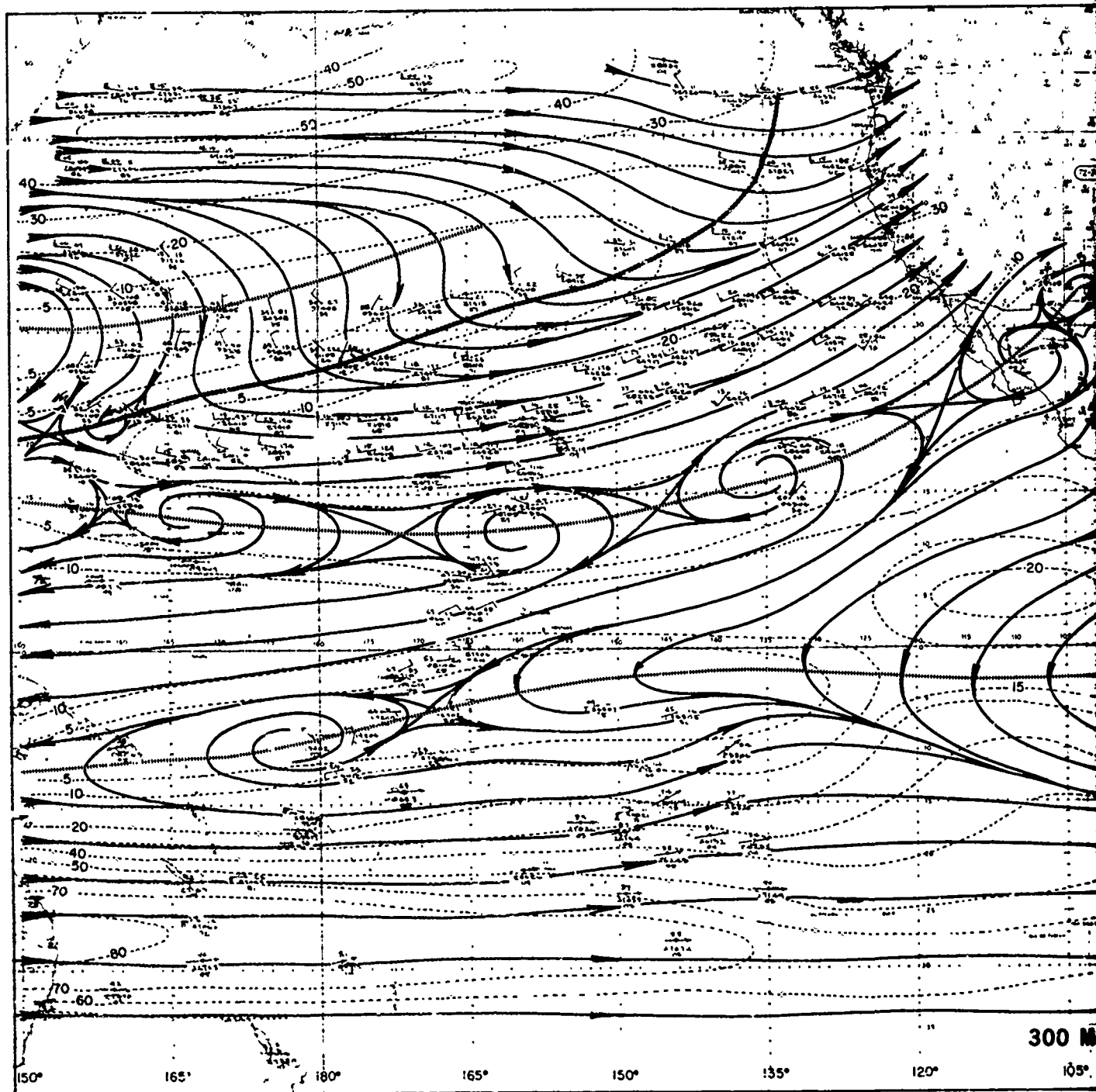
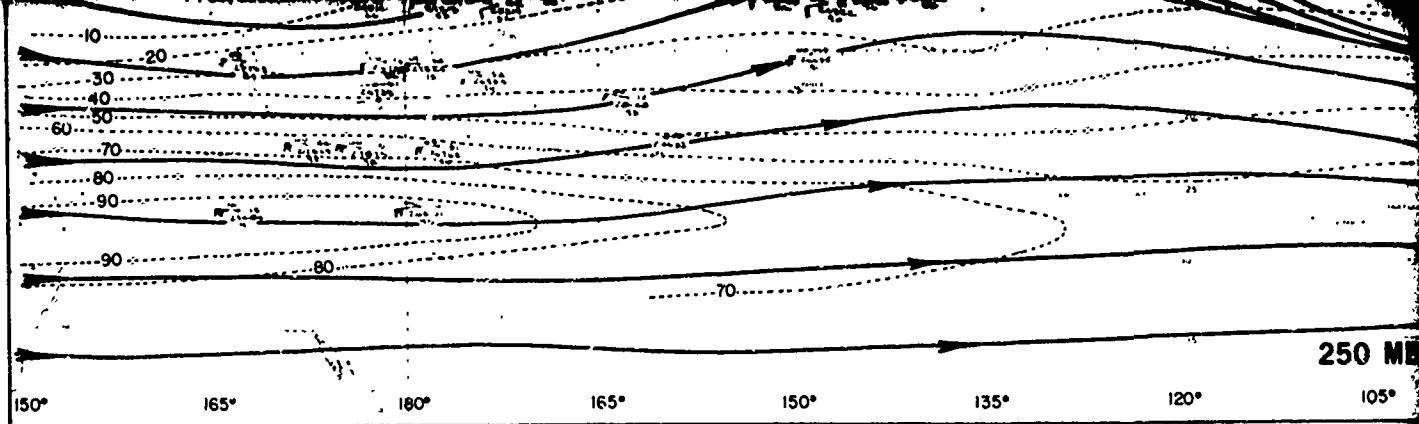
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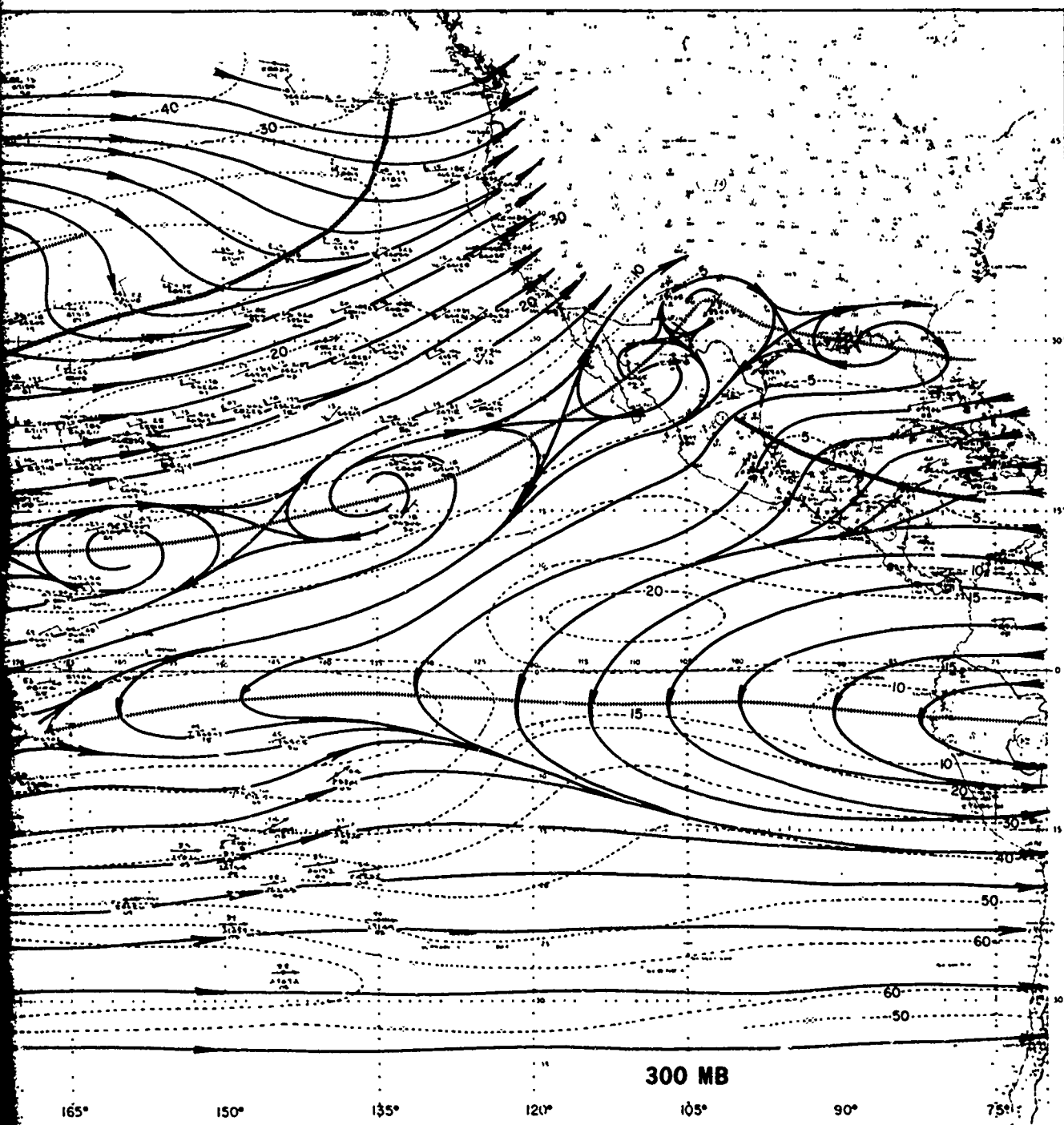
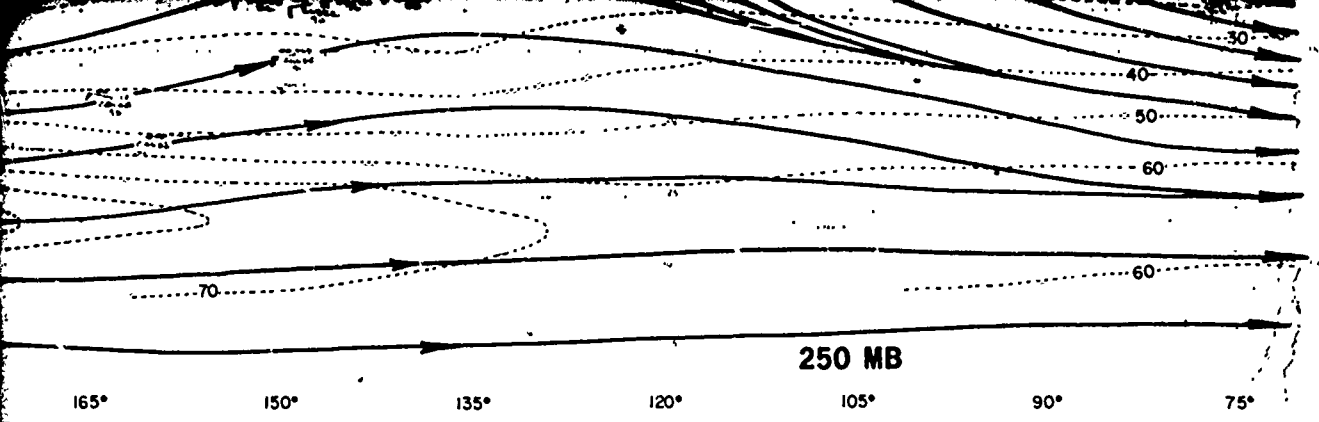
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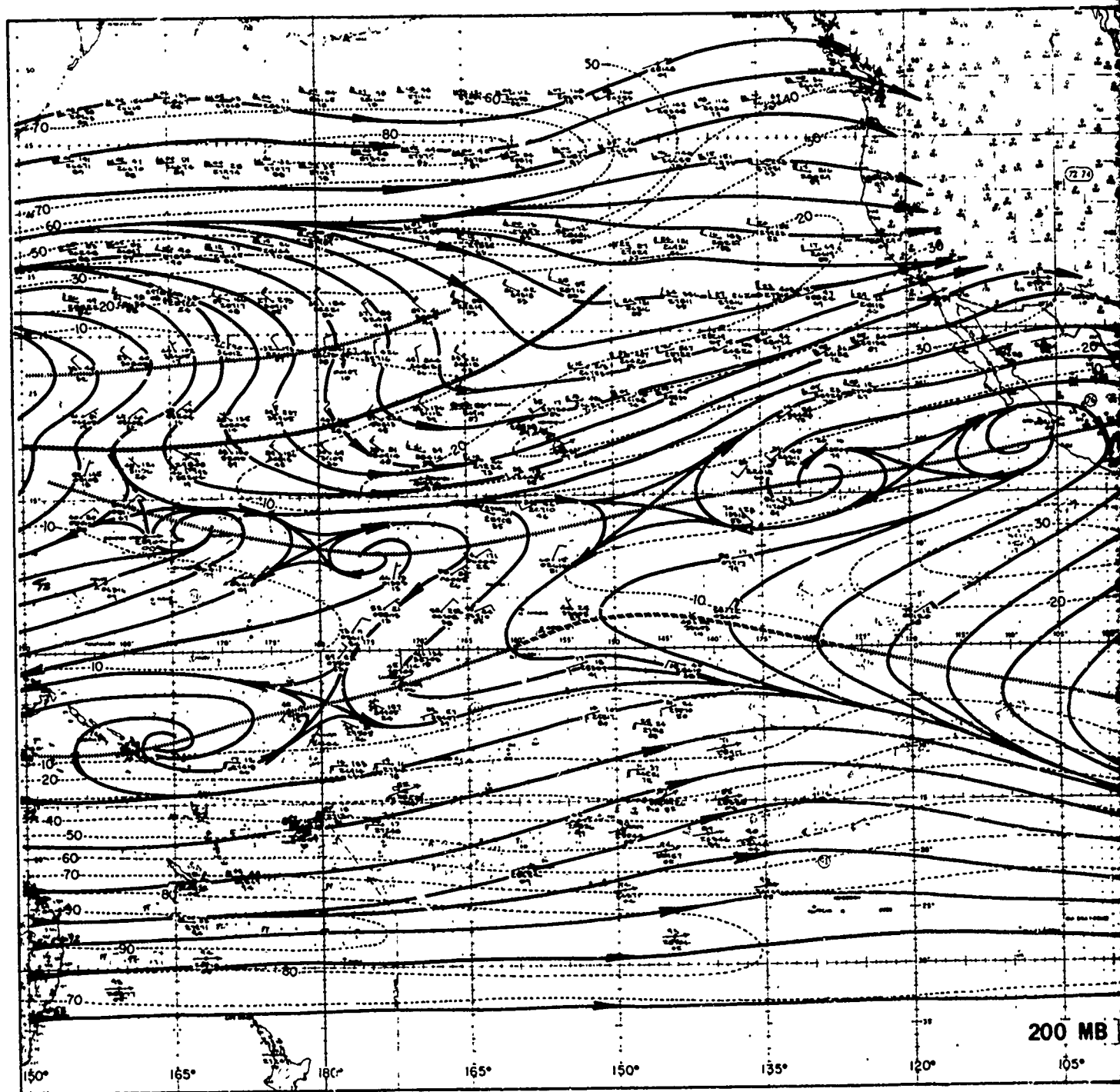
SS

 dddfff
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SEPTEMBER

Northern Hemisphere

Large changes occur between August and September.

The segment of the subtropical ridge over the southern United States has disappeared, and the TUTT is barely discernible over the Caribbean.

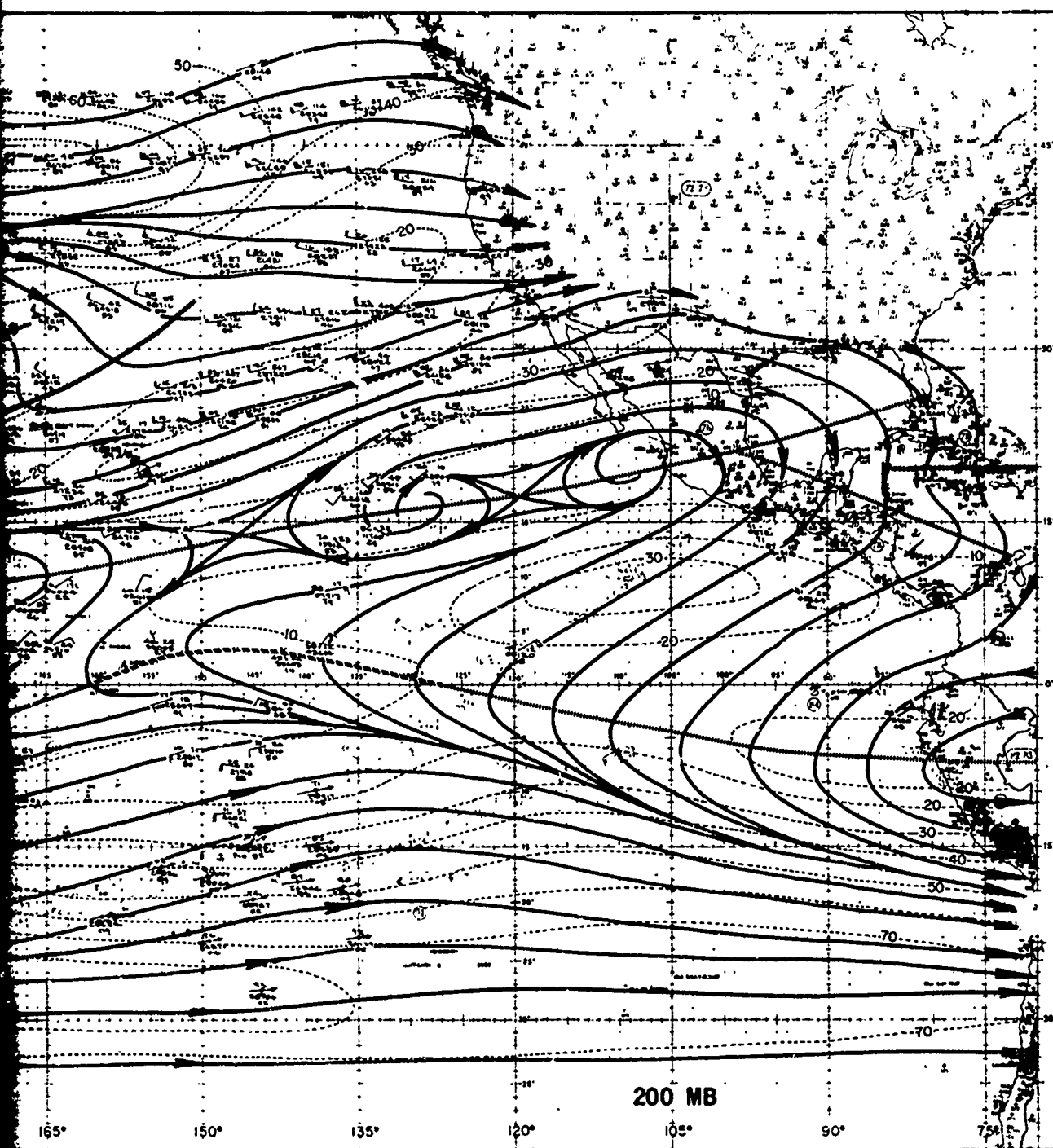
The MPT has moved southward and lost its link to higher latitudes

The subequatorial ridge has weakened between 165W and 130W of the buffer system across the

Southern Hemisphere

The temperate jet has decelerated of Australia; however, speeds are still high over Polynesia and western South America.

Equatorial Region



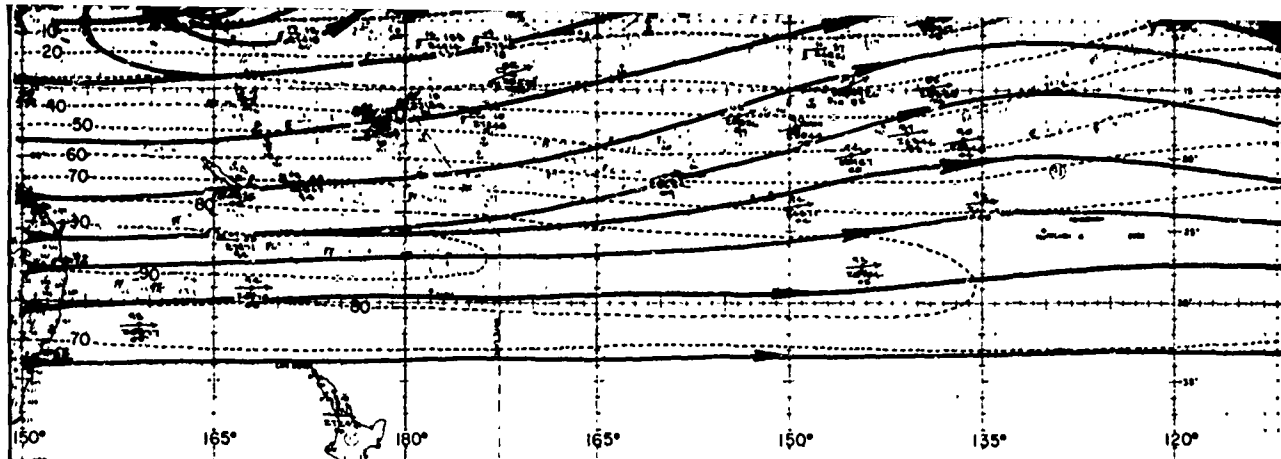
SEPTEMBER

The subequatorial ridge has moved southward. It apparently has weakened between 165W and 130W as is indicated by northward movement of the buffer system across the equator.

Southern Hemisphere

The temperate jet has decreased to near 90 kt over and just east of Australia; however, speeds have increased slightly over French

Polynesia and western South America.



SEPTEMBER

Northern Hemisphere

Large changes occur between August and September.

The segment of the subtropical ridge over the southern United States has disappeared, and the TUTT is barely discernible over the Caribbean.

The MPT has moved southward and lost its link to higher latitudes as ridging returns to the eastern Pacific off the northwest coast of the United States.

The temperate westerlies have increased to 80 kt. The maximum core remains near 45N between 180 and 165W.

The subtropical westerlies have decreased to near 30 kt eastward of Hawaii.

The subequatorial weakened between 165°W and 150°W of the buffer system.

Southern Hemisphere


The temperate zone of Australia; however, Polynesia and western

Equatorial Region

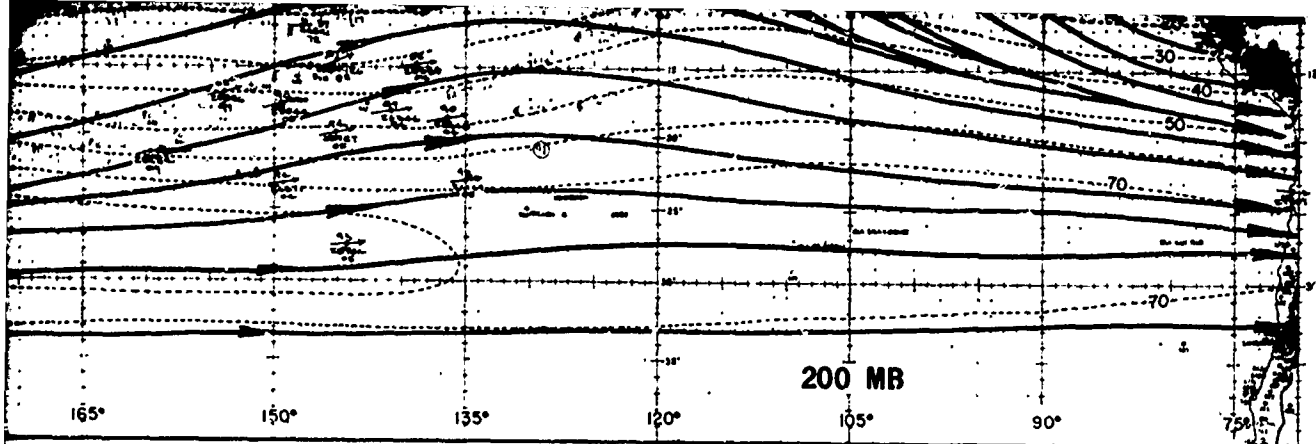
Southern Hemisphere region between 165W and 150W.

The northeastern equator remains well

PIREP Winds

EE nnnn

 dddfff
 SS

EE	-percentage of winds with an east component
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SS	-steadiness of winds in percent
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SEPTEMBER

The subequatorial ridge has moved southward. It apparently has weakened between 165W and 130W as is indicated by northward movement of the buffer system across the equator.

Southern Hemisphere

The temperate jet has decreased to near 90 kt over and just east of Australia; however, speeds have increased slightly over French Polynesia and western South America.

Equatorial Region

Southern Hemisphere westerlies have returned to the equatorial region between 165W and 130W.

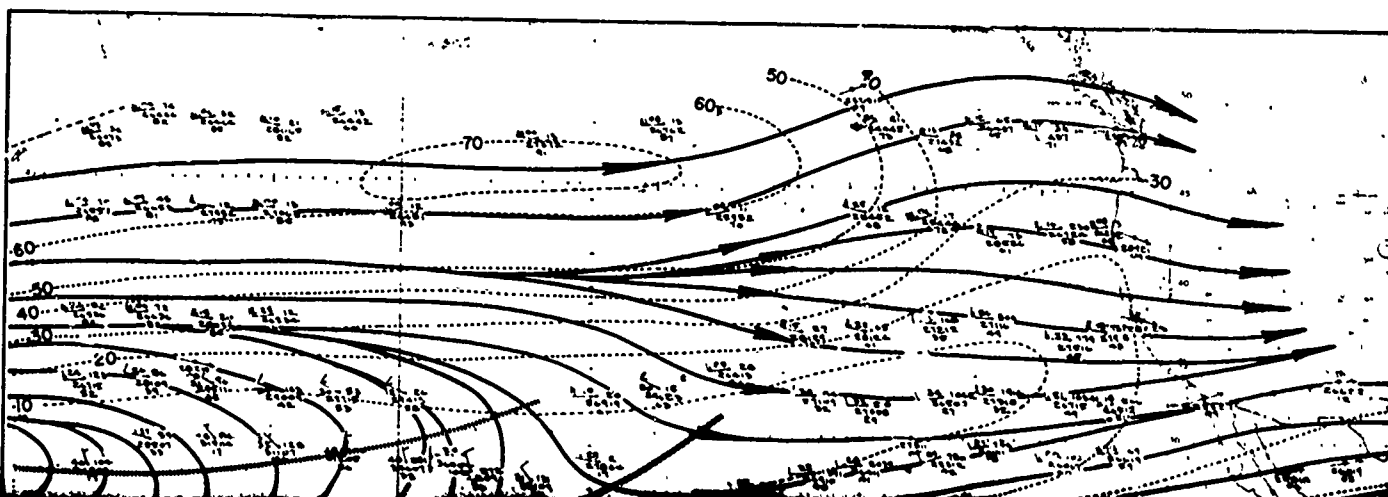
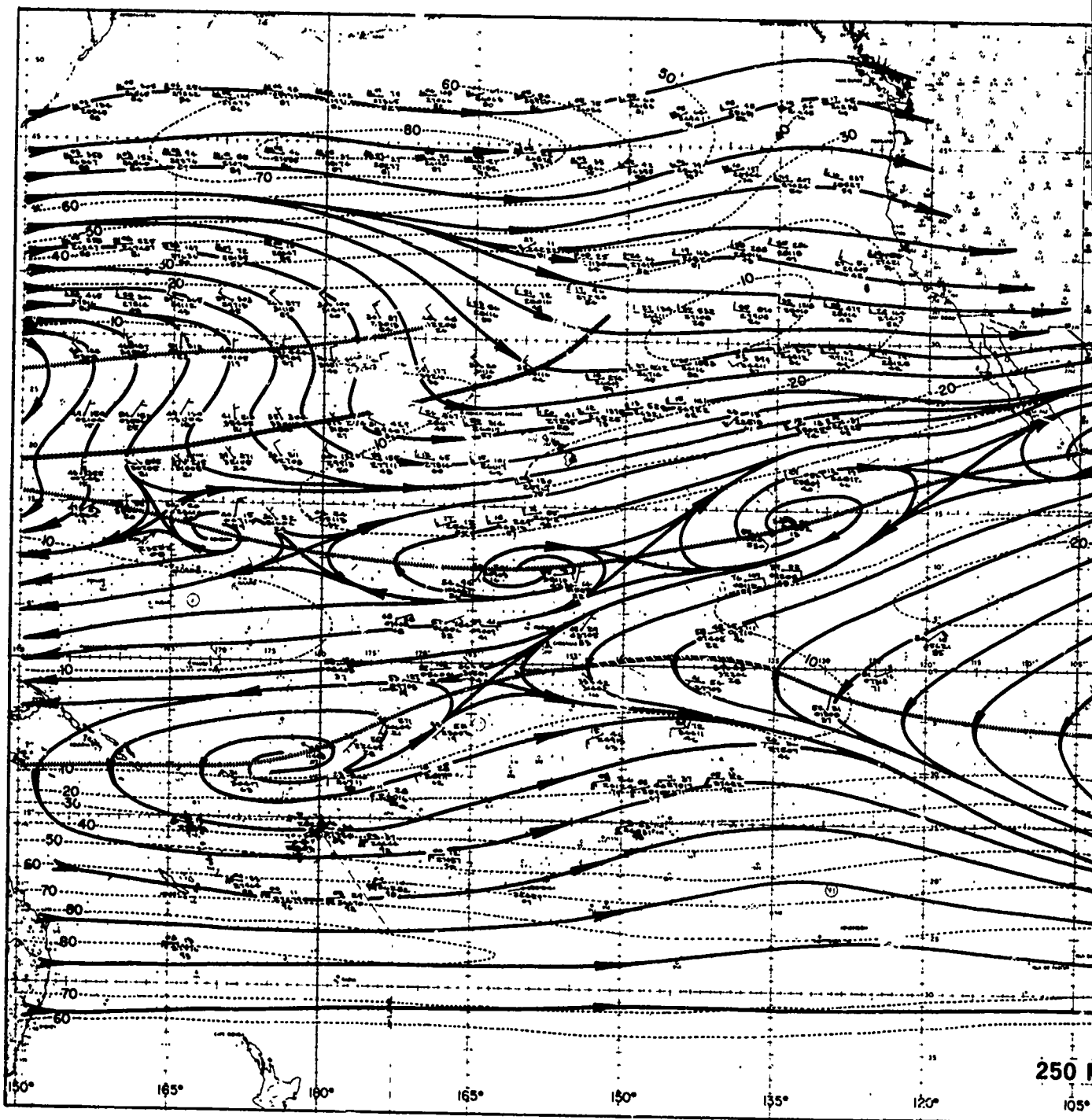
The northeasterly current over the eastern Pacific north of the equator remains well organized with speeds of near 30 kt.

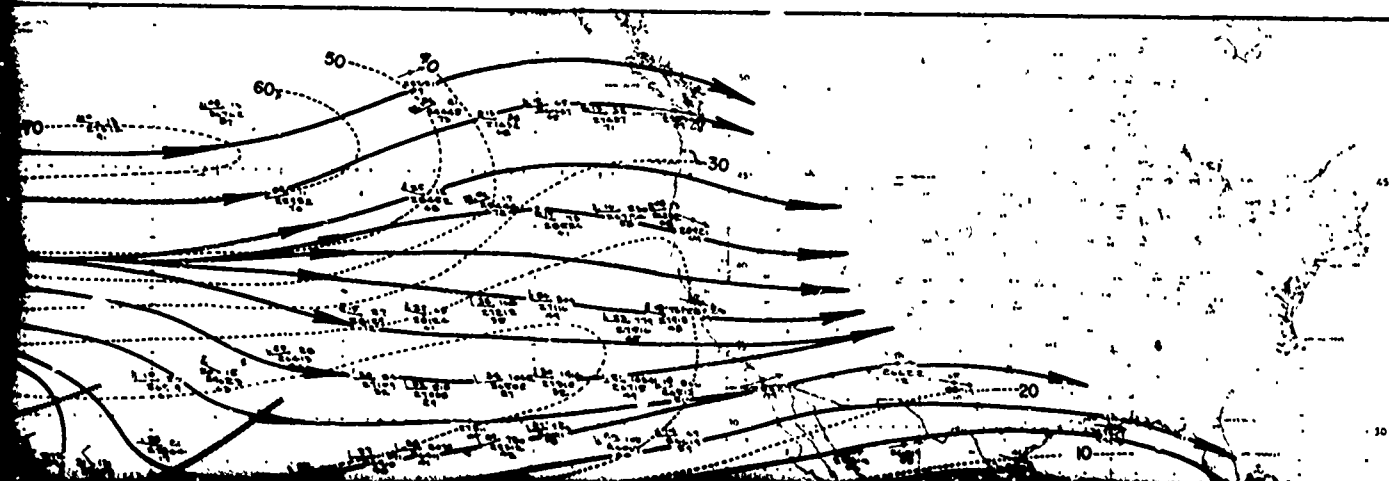
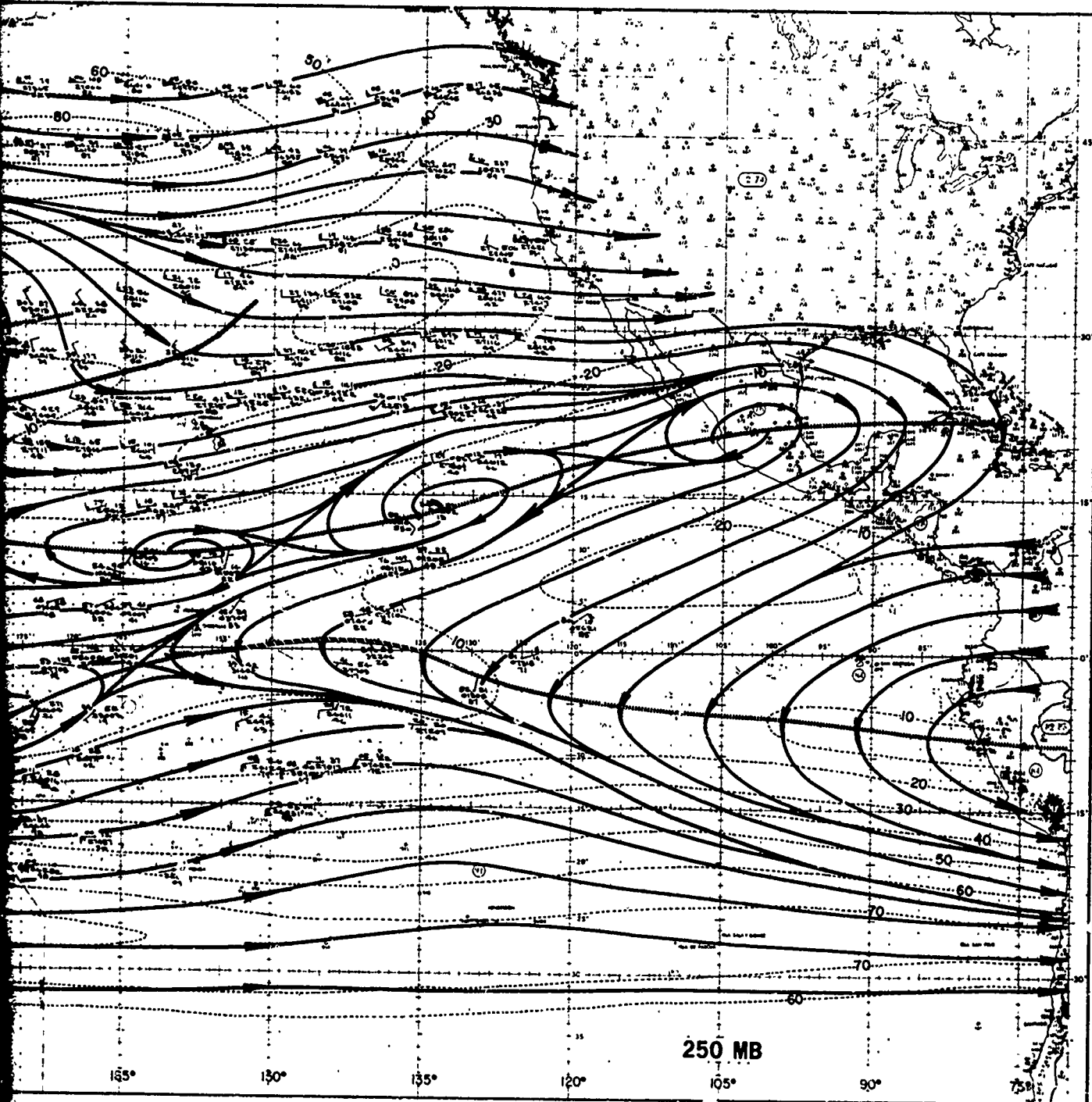
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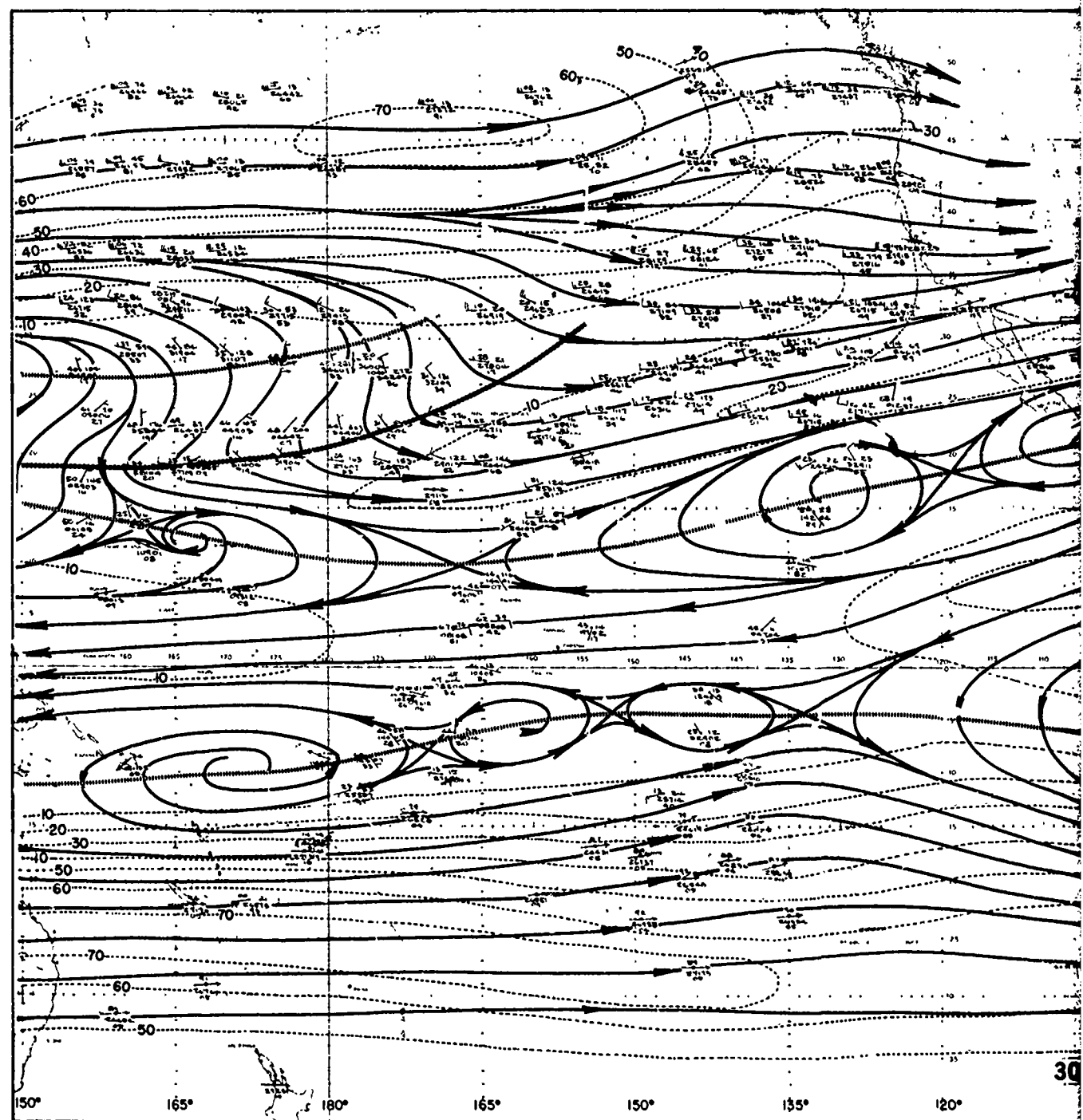
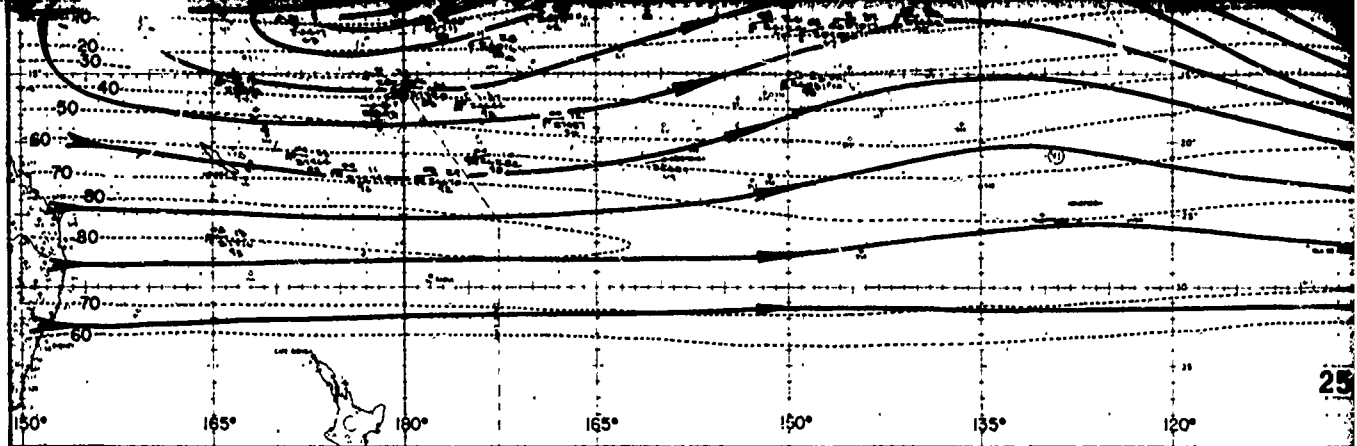
Rawins

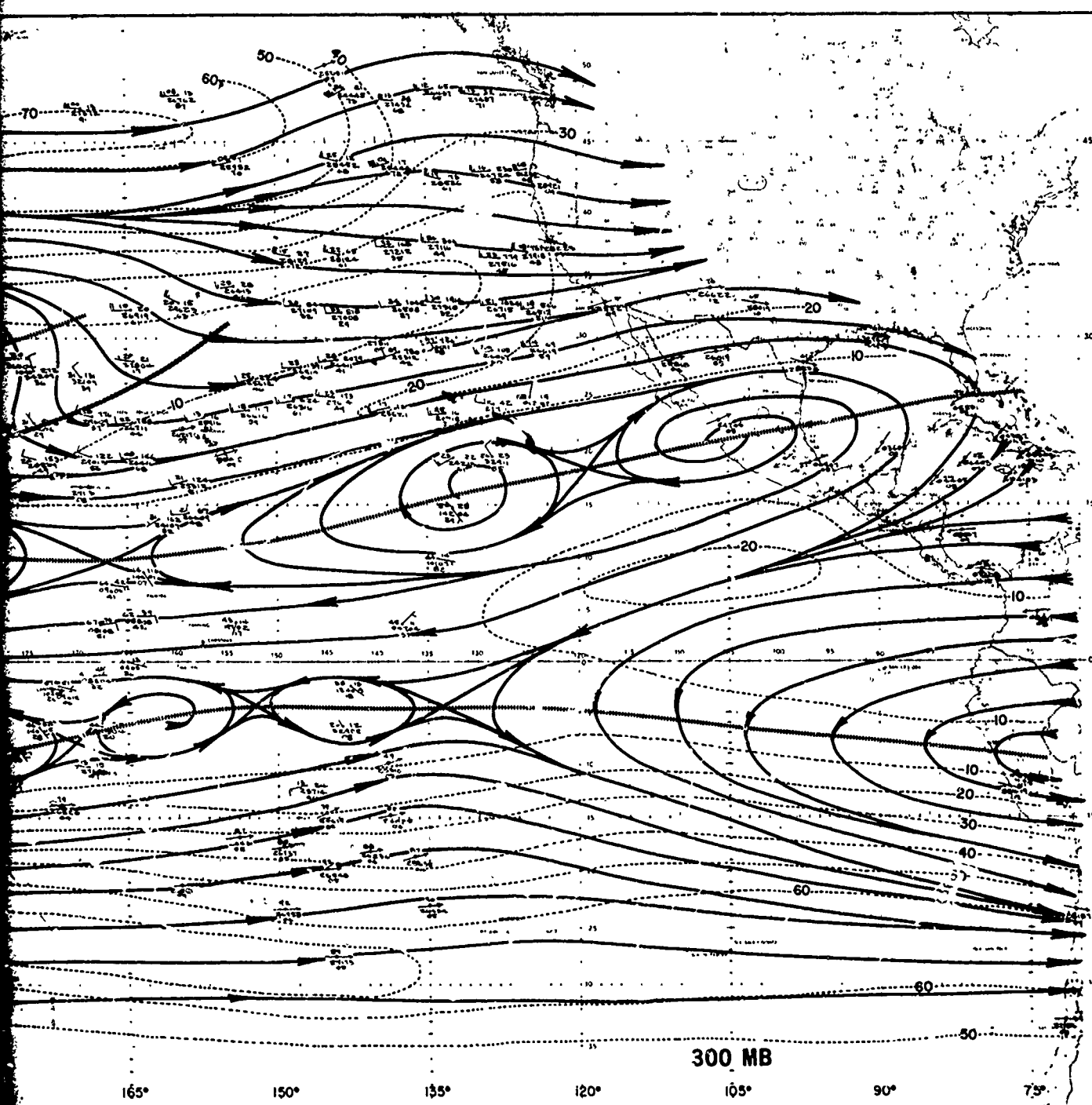
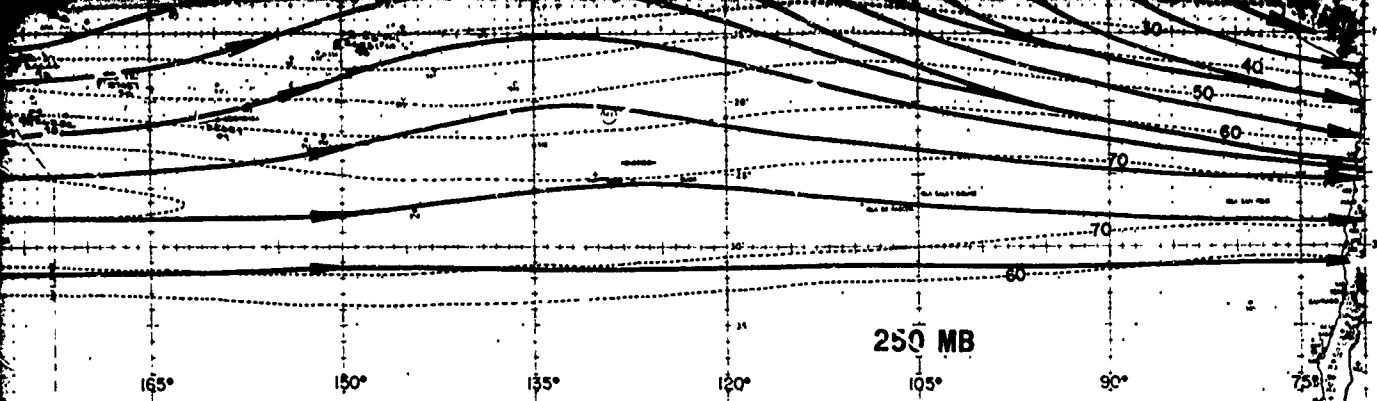
SS

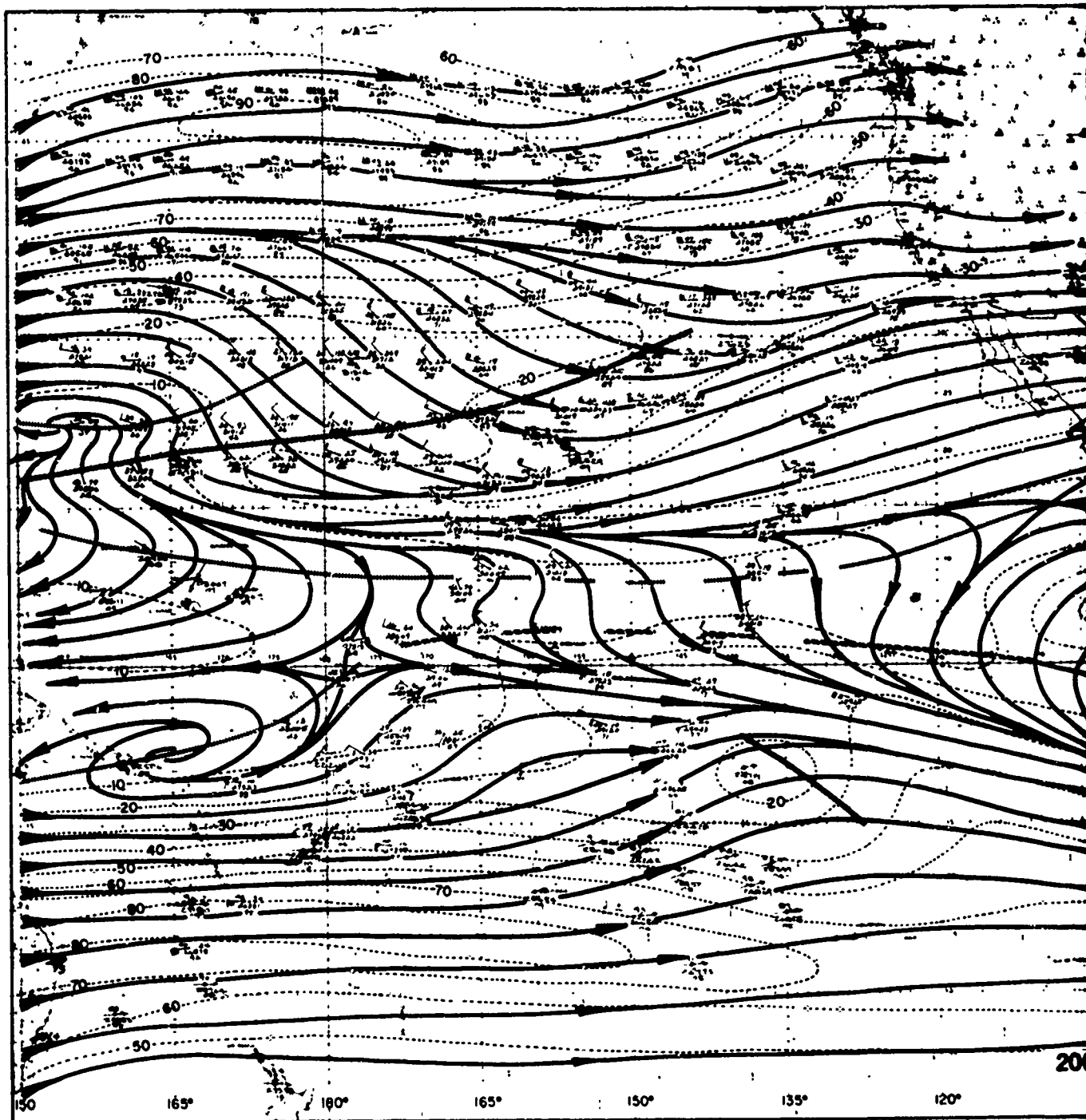
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OCTOBER

Northern Hemisphere

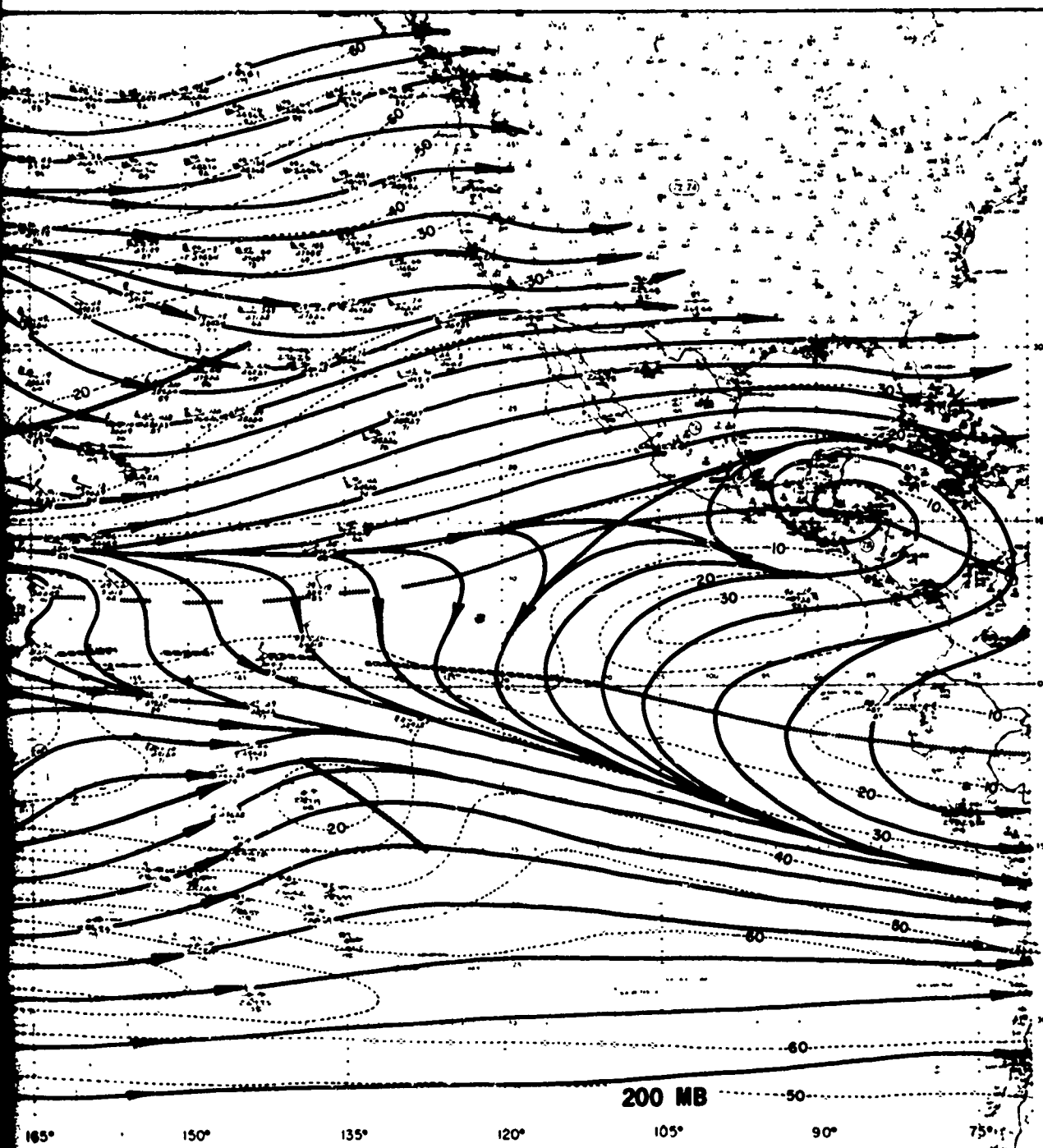
The temperate westerlies have continued to increase. The maximum speed of near 90 kt remains near the dateline just north of 45°N; however, there is a marked eastward extension of the high speed ribbon (similar to that of June), and a core of greater than 60 kt enters southwestern Canada.

The MPT has weakened considerably and moved southward.

Southern Hemisphere

The subtropical ridge near 180.

Relatively strong winds equatorial region. The M between the re-establishment temperate westerlies to t



OCTOBER

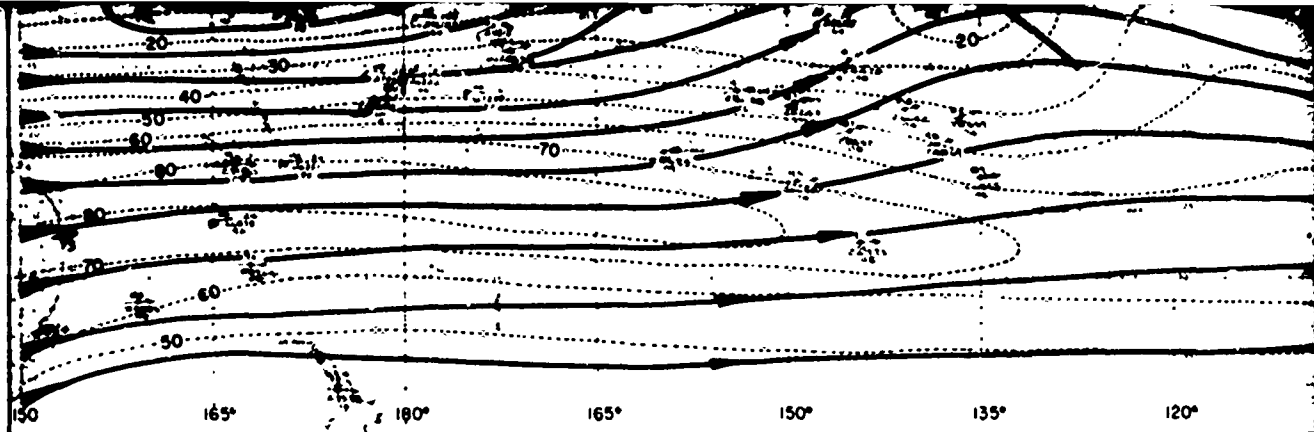
Southern Hemisphere

increase. The maximum
north of 45N; however,
speed ribbon (similar
enters southwestern

The subtropical ridge is located near 10S at 155E and terminates
near 180.

Southward.

Relatively strong westerlies of 25 to 30 kt have returned to the
equatorial region. The minimum speed over French Polynesia near 10S,
between the re-established tropical westerlies and the stronger
temperate westerlies to the south, indicates redevelopment of the TUTT.



OCTOBER

Northern Hemisphere

The temperate westerlies have continued to increase. The maximum speed of near 90 kt remains near the dateline just north of 45N; however, there is a marked eastward extension of the high speed ribbon (similar to that of June), and a core of greater than 60 kt enters southwestern Canada.

The MPT has weakened considerably and moved southward.

A very thin ribbon of 30-kt subtropical westerlies extends from just south of Hawaii to the southern California coast.

The subtropical ridge has weakened markedly between 180 and 120W and moved southward. A strong anticyclonic cell remains north of 15N over Central America.

Southern Hemisphere

The subtropical ridge has moved southward near 180.


Relatively strong westerlies are present between the re-established temperate westerlies and the equator.

The temperate westerlies core has moved equatorward over western South America.

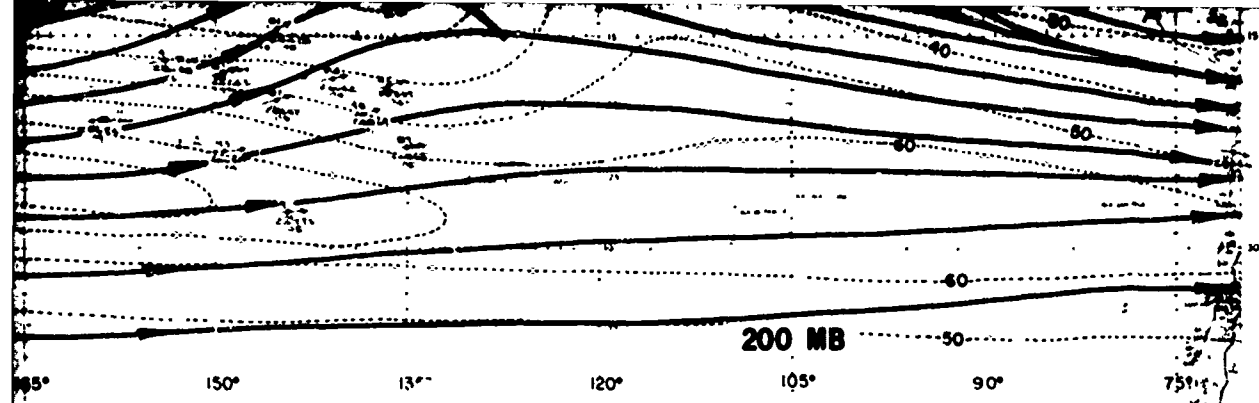
Equatorial Region

Westerlies have moved southward near 130W. The easterly wind core remains well off the equator.

PIREP Winds

EE nnnn

 dddfff
 SS

EE	-percentage of winds with an east component
nnnn	-number of observations
ddd	-mean resultant wind direction
fff	-mean resultant wind speed in knots (flag = 50 knots, long barb = 10 knots, short barb = 5 knots)
SS	-steadiness of winds in percent
NN	-number of years of record



OCTOBER

Southern Hemisphere

increase. The maximum
north of 45N; however,
speed ribbon (similar
enters southwestern

southward.

lies extends from
east.

between 180 and 120W
remains north of 15N

The subtropical ridge is located near 10S at 155E and terminates near 180.

Relatively strong westerlies of 25 to 30 kt have returned to the equatorial region. The minimum speed over French Polynesia near 10S, between the re-established tropical westerlies and the stronger temperate westerlies to the south, indicates redevelopment of the TUTT.


The temperate westerlies have decreased throughout. The maximum core has moved equatorward over the western Pacific and poleward over western South America.

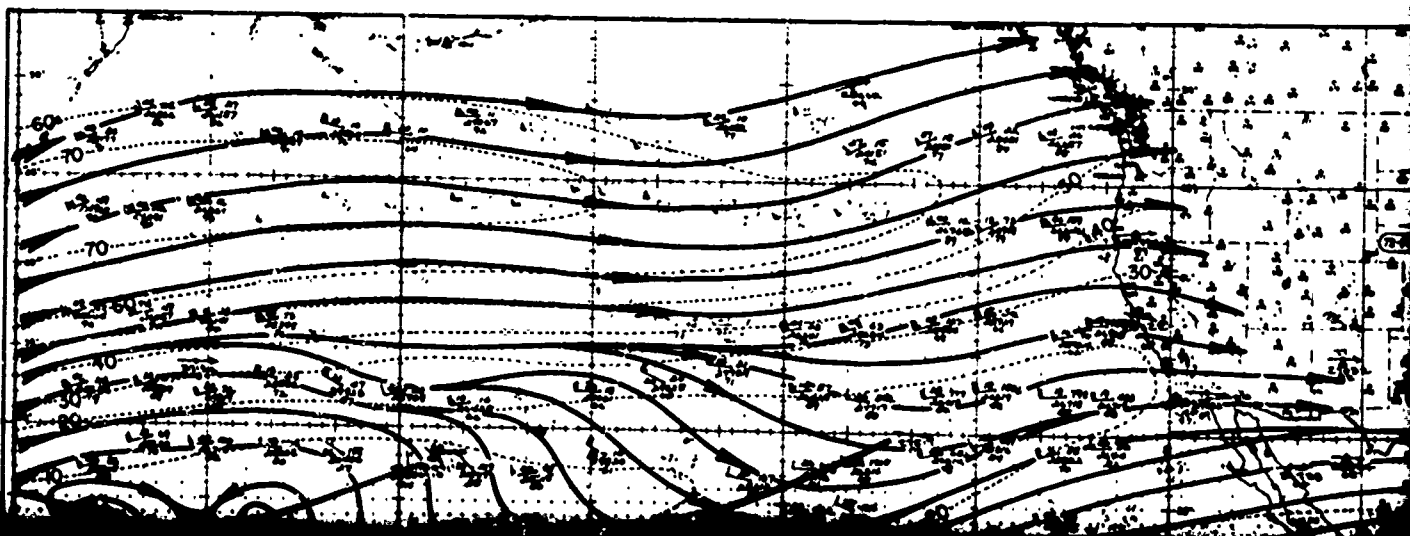
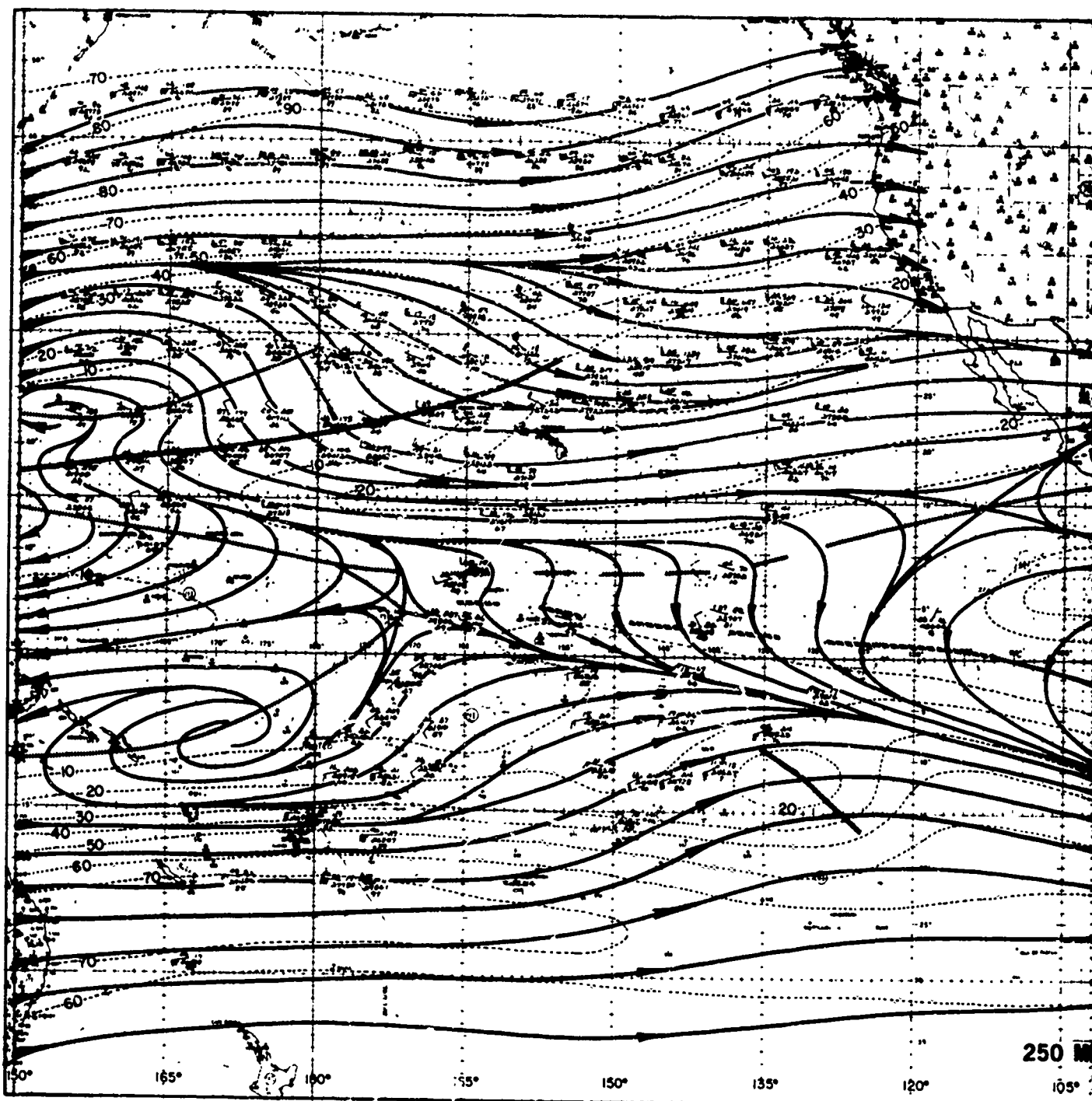
Equatorial Region

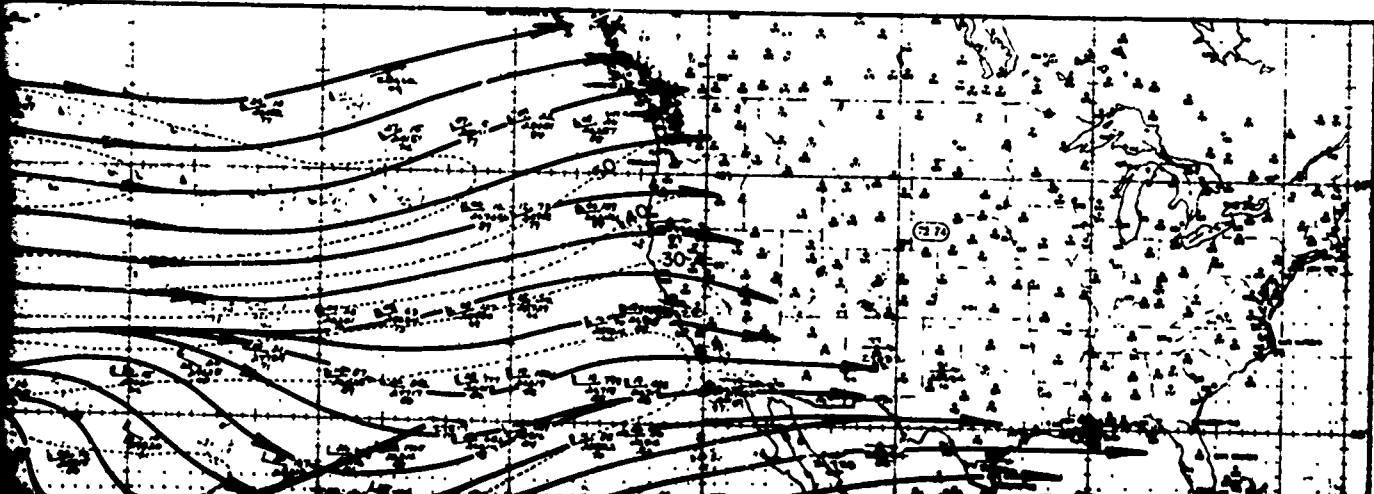
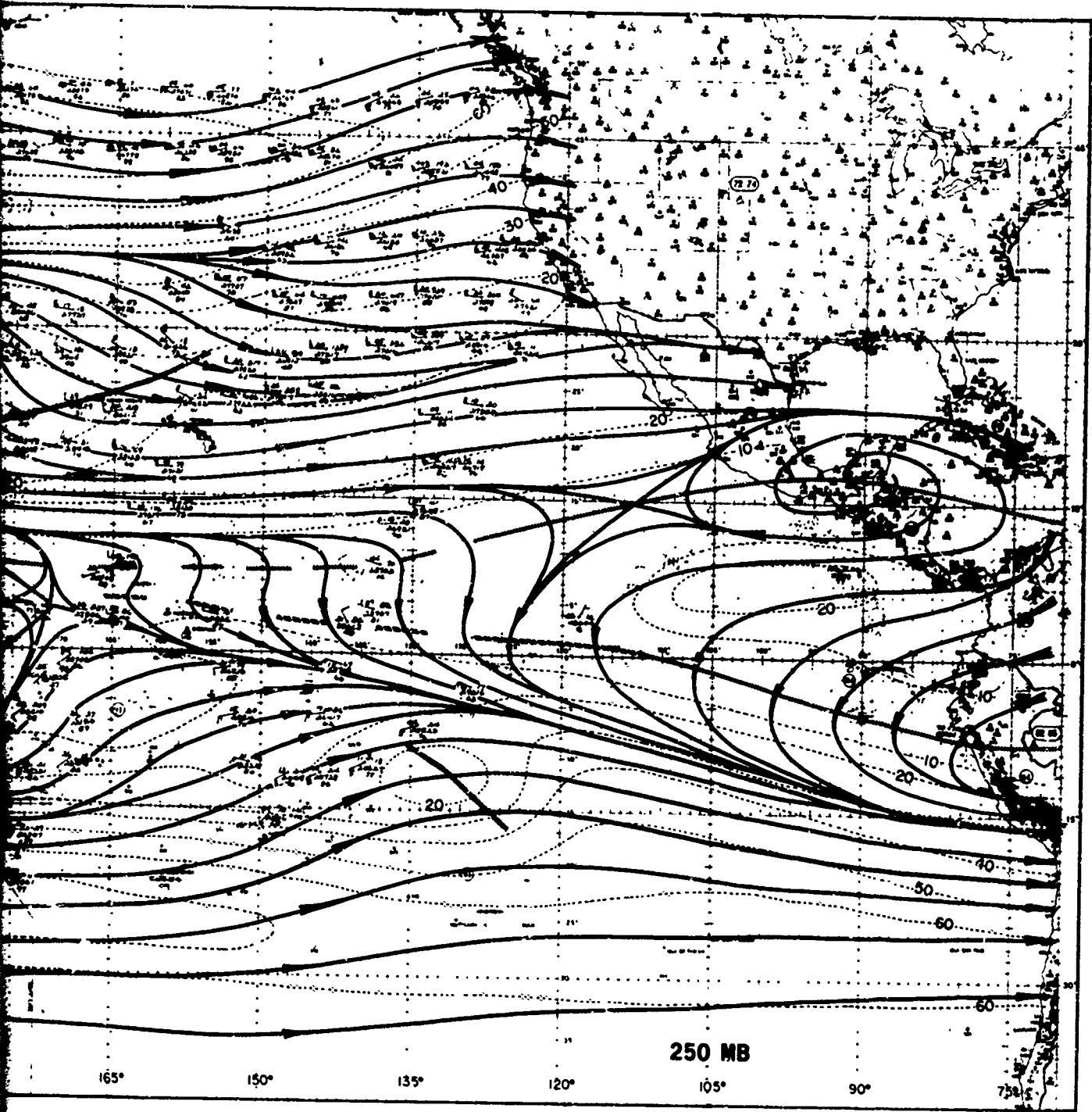
Westerlies have returned to the equatorial region between 180W and 130W. The easterly current over the eastern Pacific north of the equator remains well organized with maximum speeds near 30 kt.

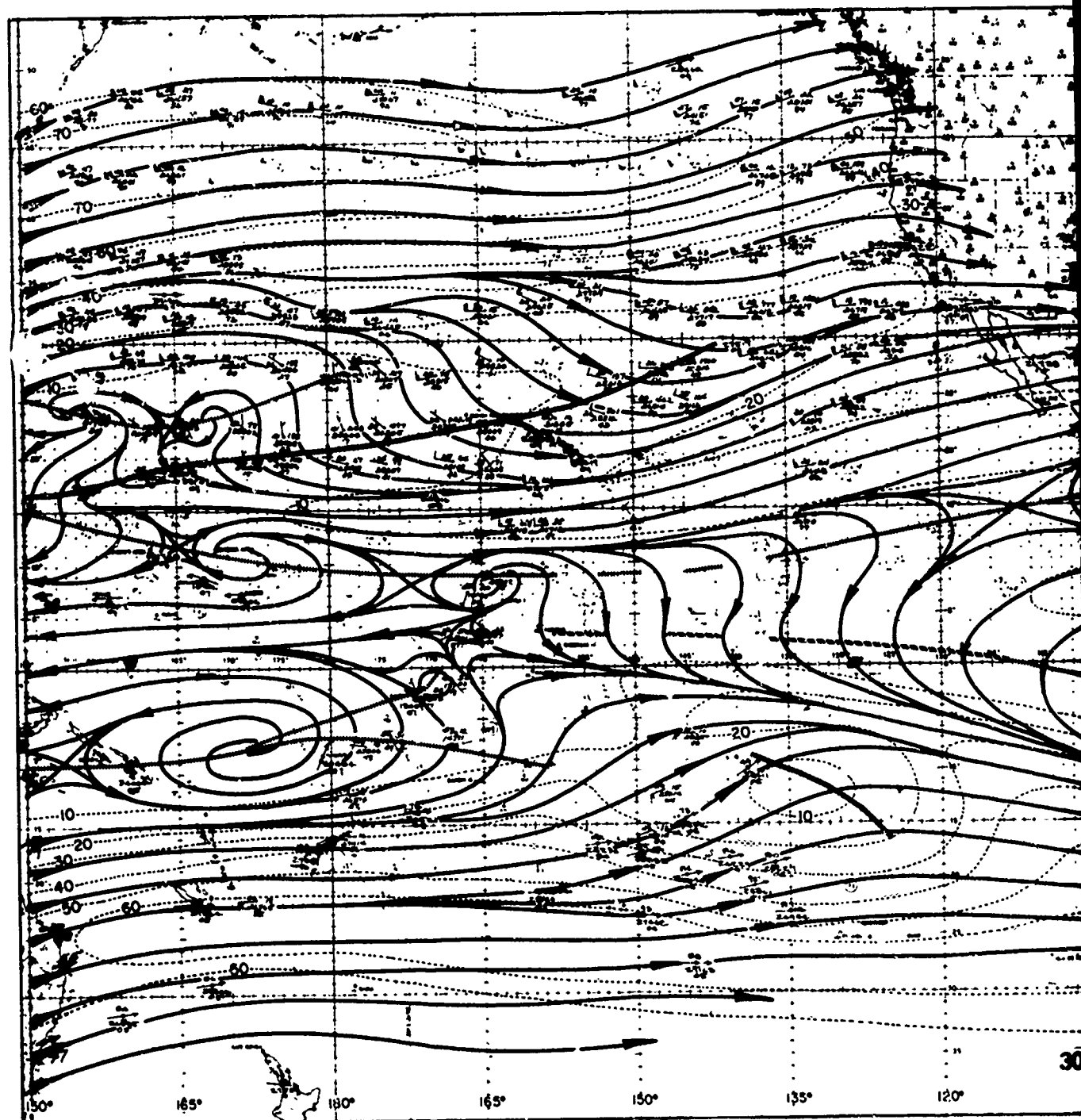
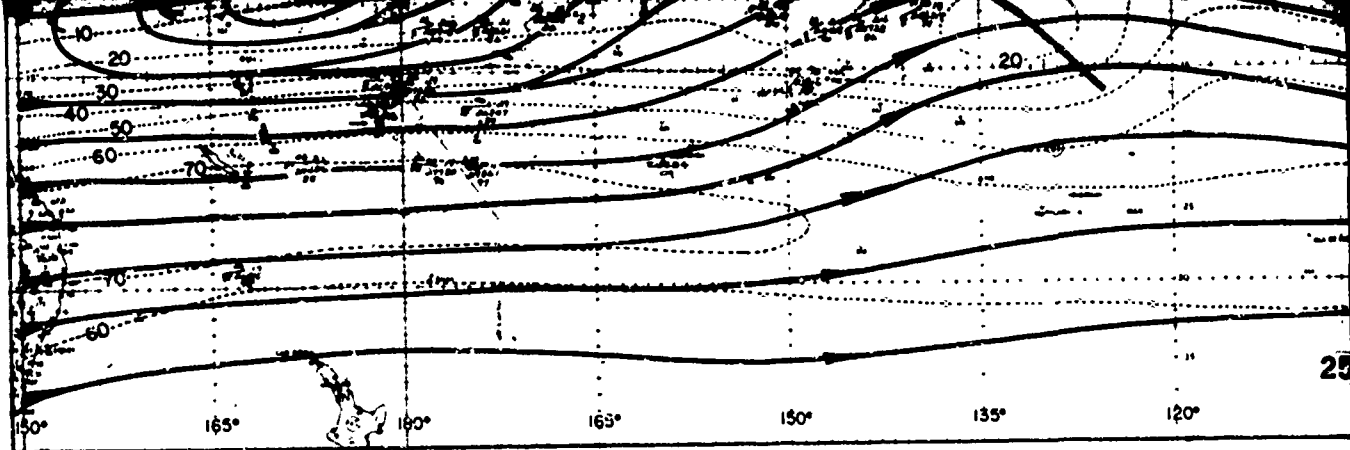
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NN	-number of years of record

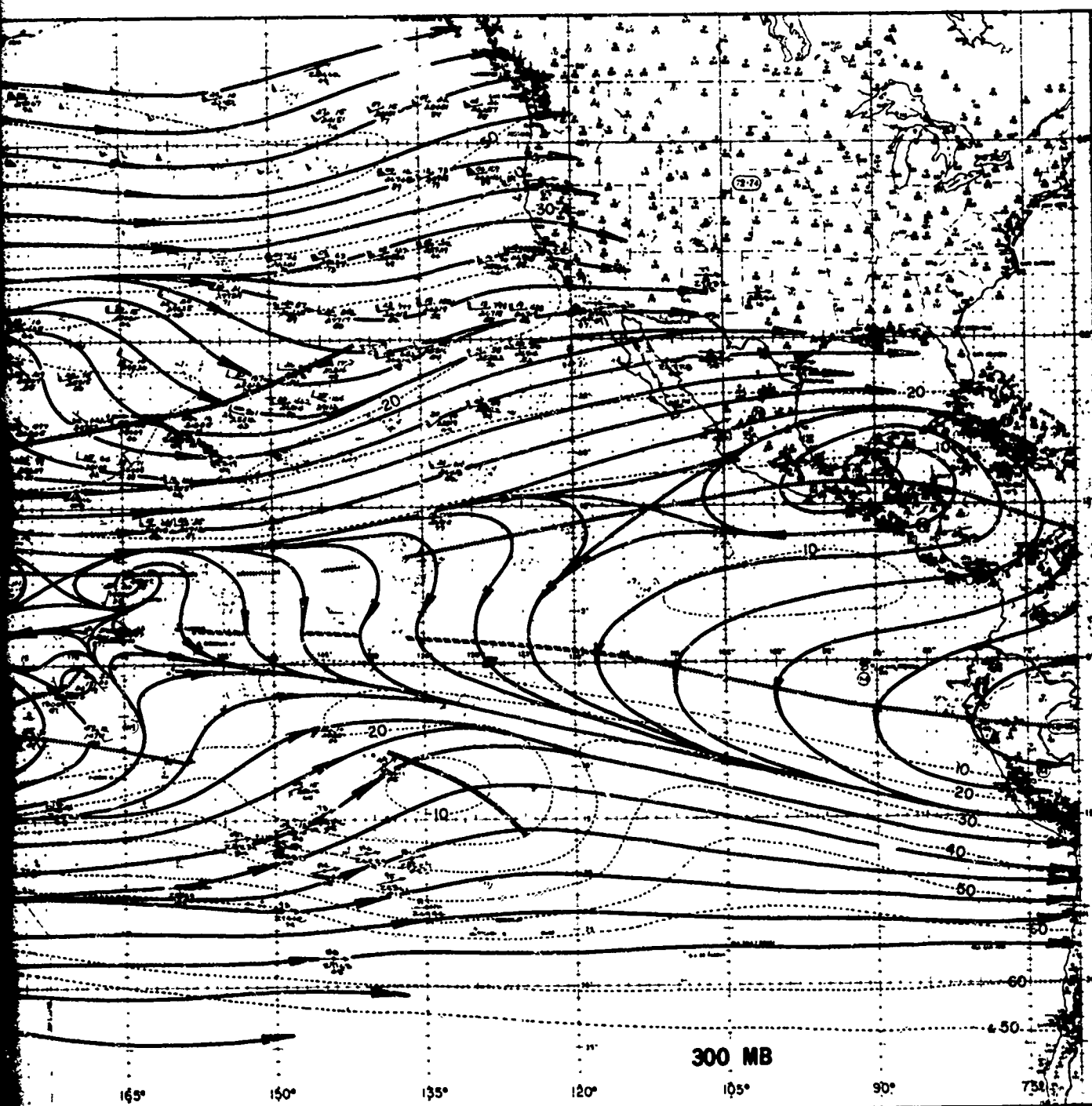
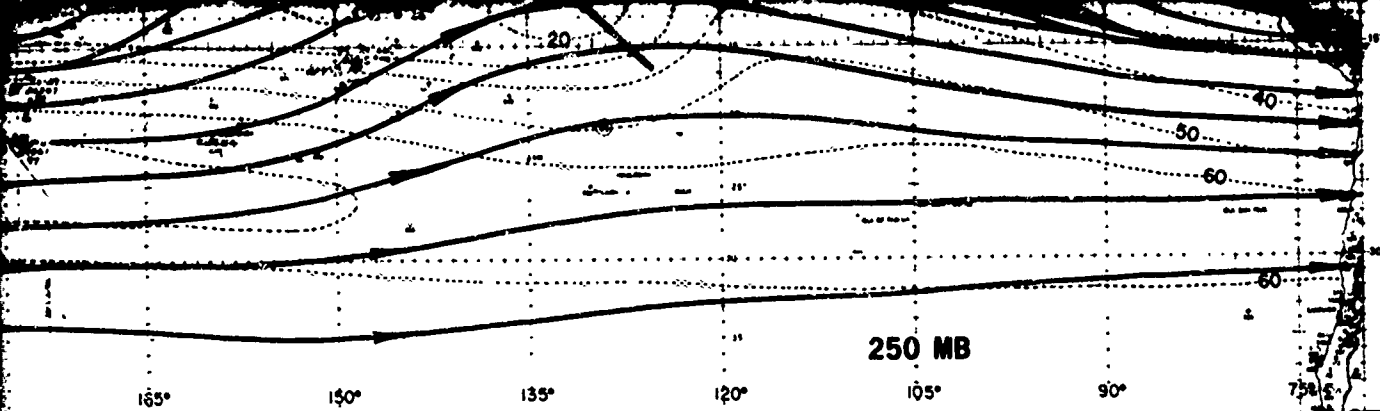
Rawins

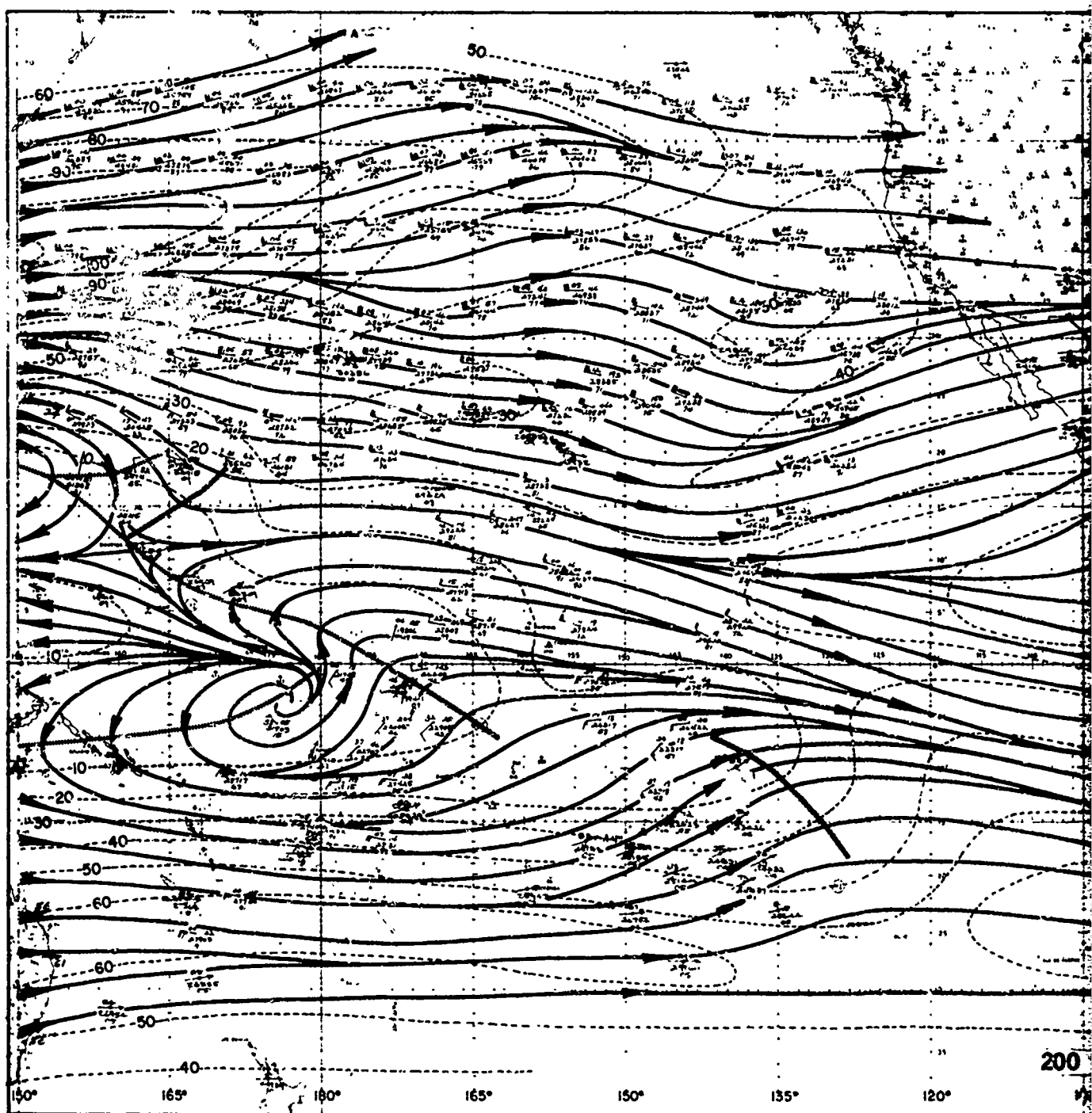
SS

 dddfff
 NN











NOVEMBER

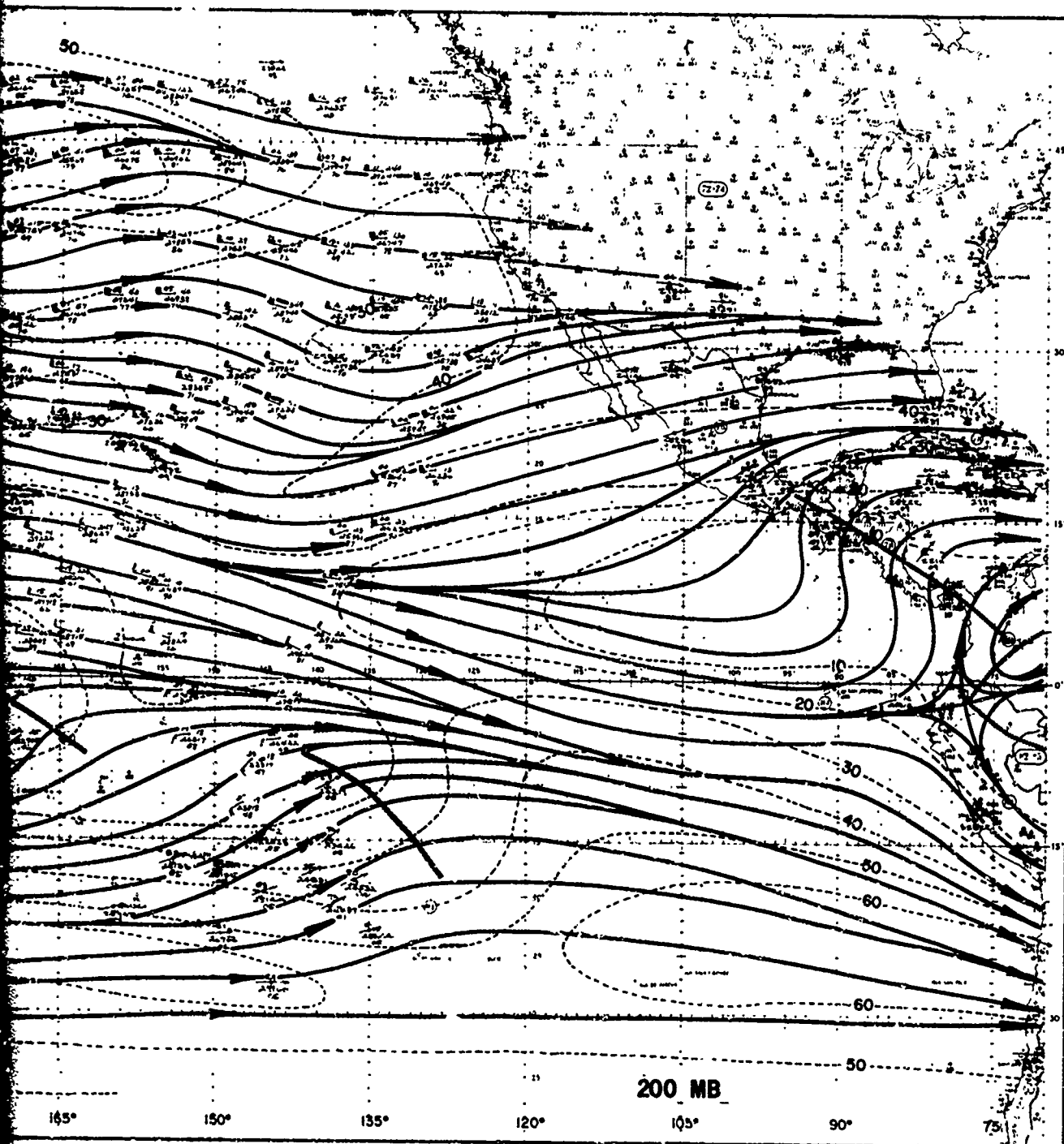
Northern Hemisphere

The temperate westerlies change considerably from October to November. The October maximum in the region of the dateline at 45N has disappeared, and the winter pattern of the highest speeds over Japan near 35N has been re-established. The eastward extension of the high speeds in October has disappeared, and relative minimum speeds exist off the western coast of North America.

The subtropical ridge has a weak ridge extends from Central America.

Southern Hemisphere

The temperate westerlies in the Pacific; however, they have to the re-establishment of



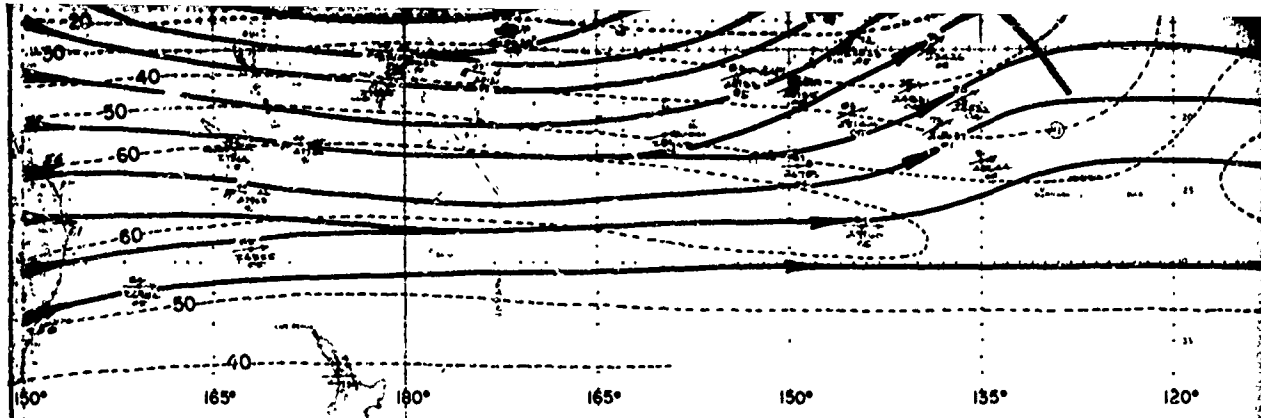
NOVEMBER

...y from October to
the dateline at 45N
highest speeds over
stward extension of
relative minimum
ica.

The subtropical ridge in the eastern Pacific has disappeared, and a weak ridge extends from northern South America northwestward over Central America.

Southern Hemisphere

The temperate westerlies have continued to decrease in the western Pacific; however, they have increased over western South America due to the re-establishment of the mid-tropospheric north-south pressure



NOVEMBER

Northern Hemisphere

The temperate westerlies change considerably from October to November. The October maximum in the region of the dateline at 45N has disappeared, and the winter pattern of the highest speeds over Japan near 35N has been re-established. The eastward extension of the high speeds in October has disappeared, and relative minimum speeds exist off the western coast of North America.

The subtropical current has increased in the eastern Pacific. Core speeds of near 45 kt extend from 22N, 135W eastward across Baja California.

The MPT has essentially disappeared. It is split into two weak segments, one west of 180 and the other east of weather ship November (30N, 140W) and Hawaii.

The subtropical a weak ridge extends Central America.


Southern Hemisphere

The temperate Pacific; however, to the re-establish equatorward of the

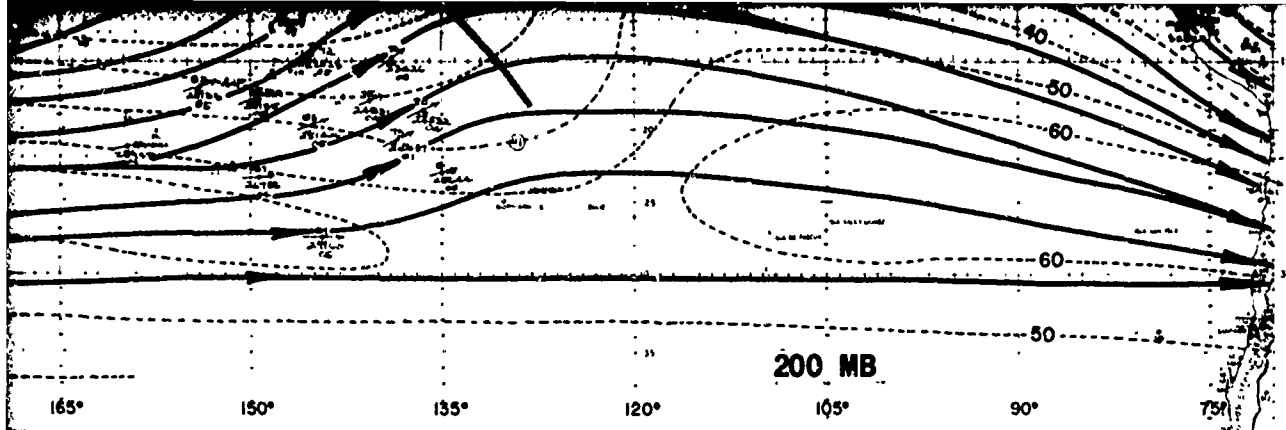
Equatorial Region

Westerlies have ward to South America eastern Pacific north of summer has disappeared

PIREP Winds

EE nnnn

 dddfff
 SS

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NOVEMBER

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weather ship November

The subtropical ridge in the eastern Pacific has disappeared, and a weak ridge extends from northern South America northwestward over Central America.

Southern Hemisphere

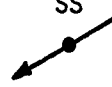
The temperate westerlies have continued to decrease in the western Pacific; however, they have increased over western South America due to the re-establishment of the subtropical northwesterly stream equatorward of the TUTT.

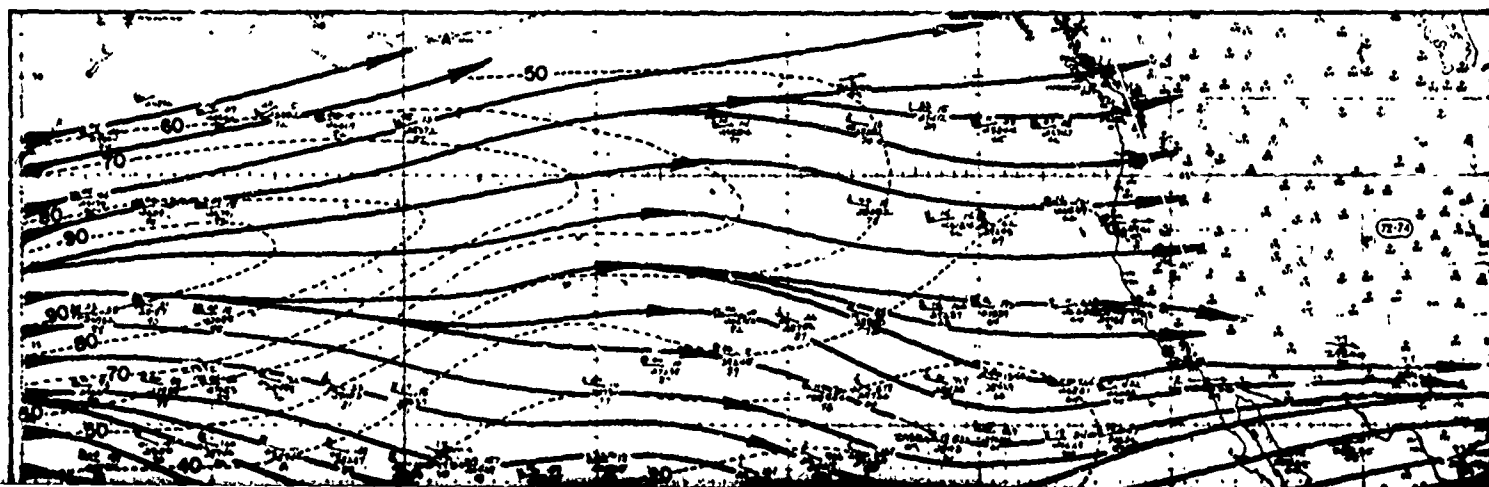
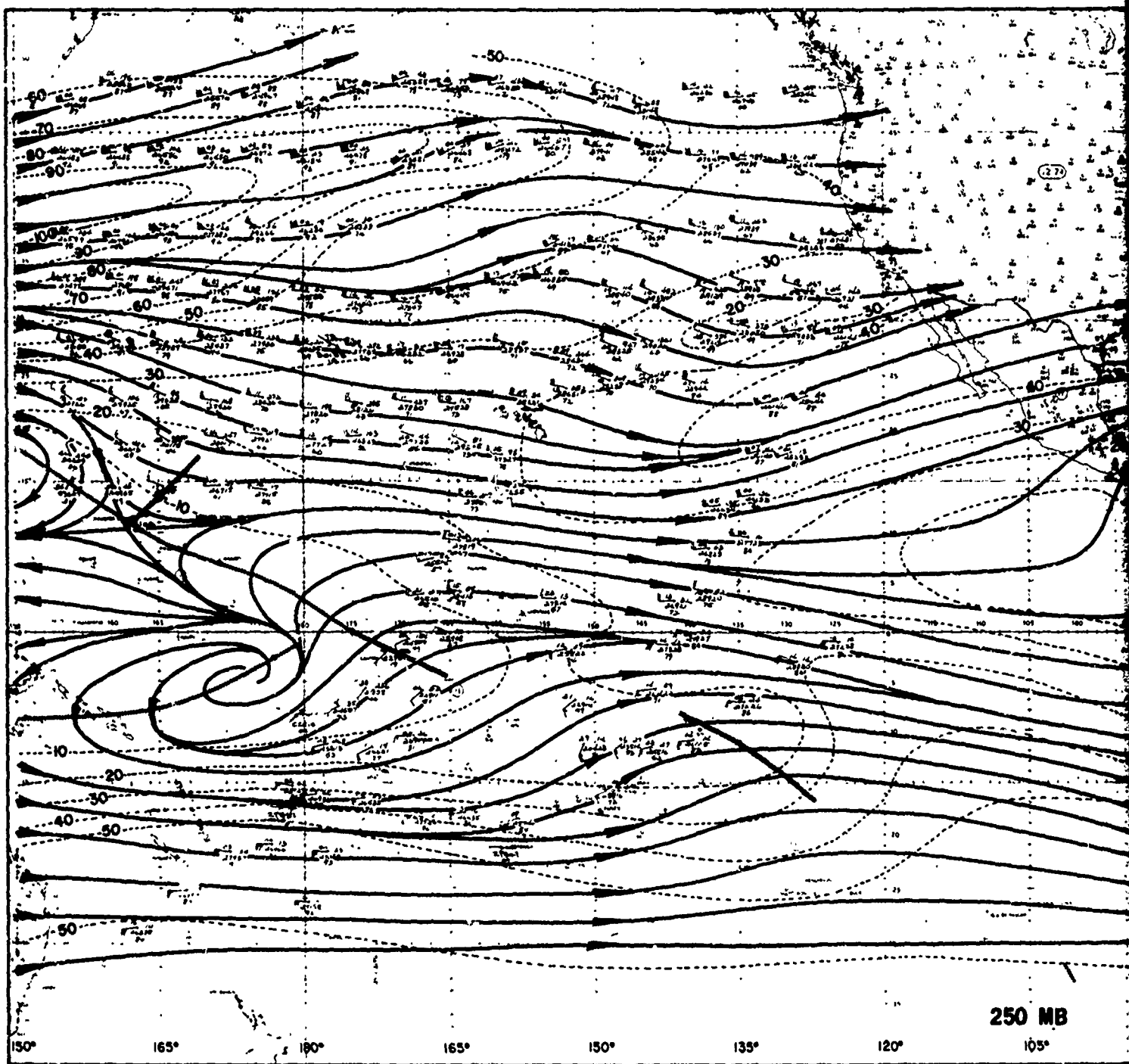
Equatorial Region

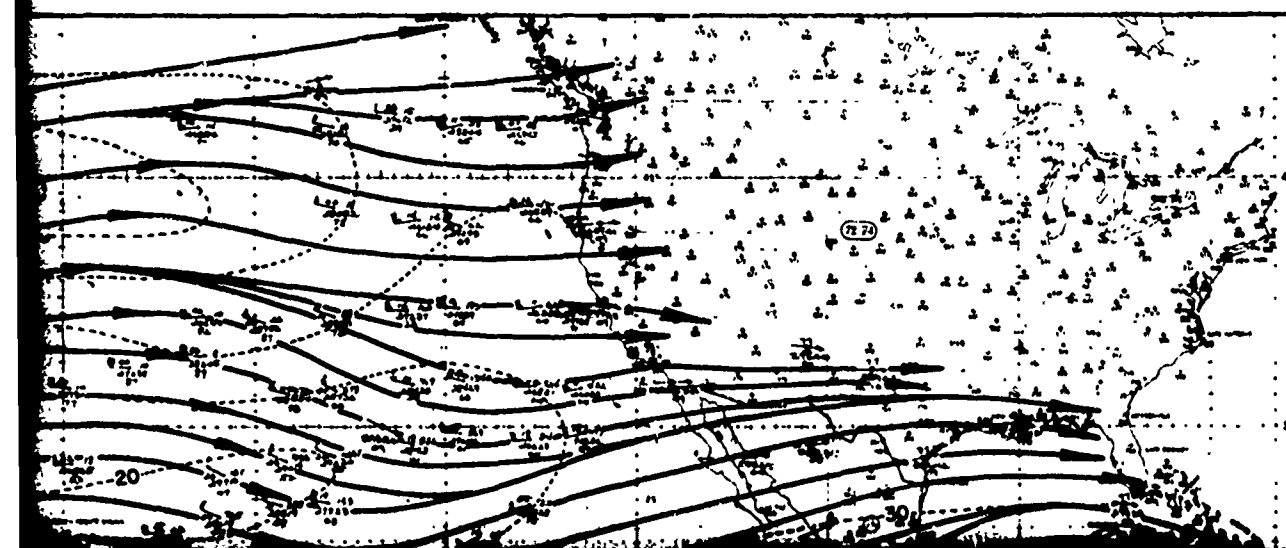
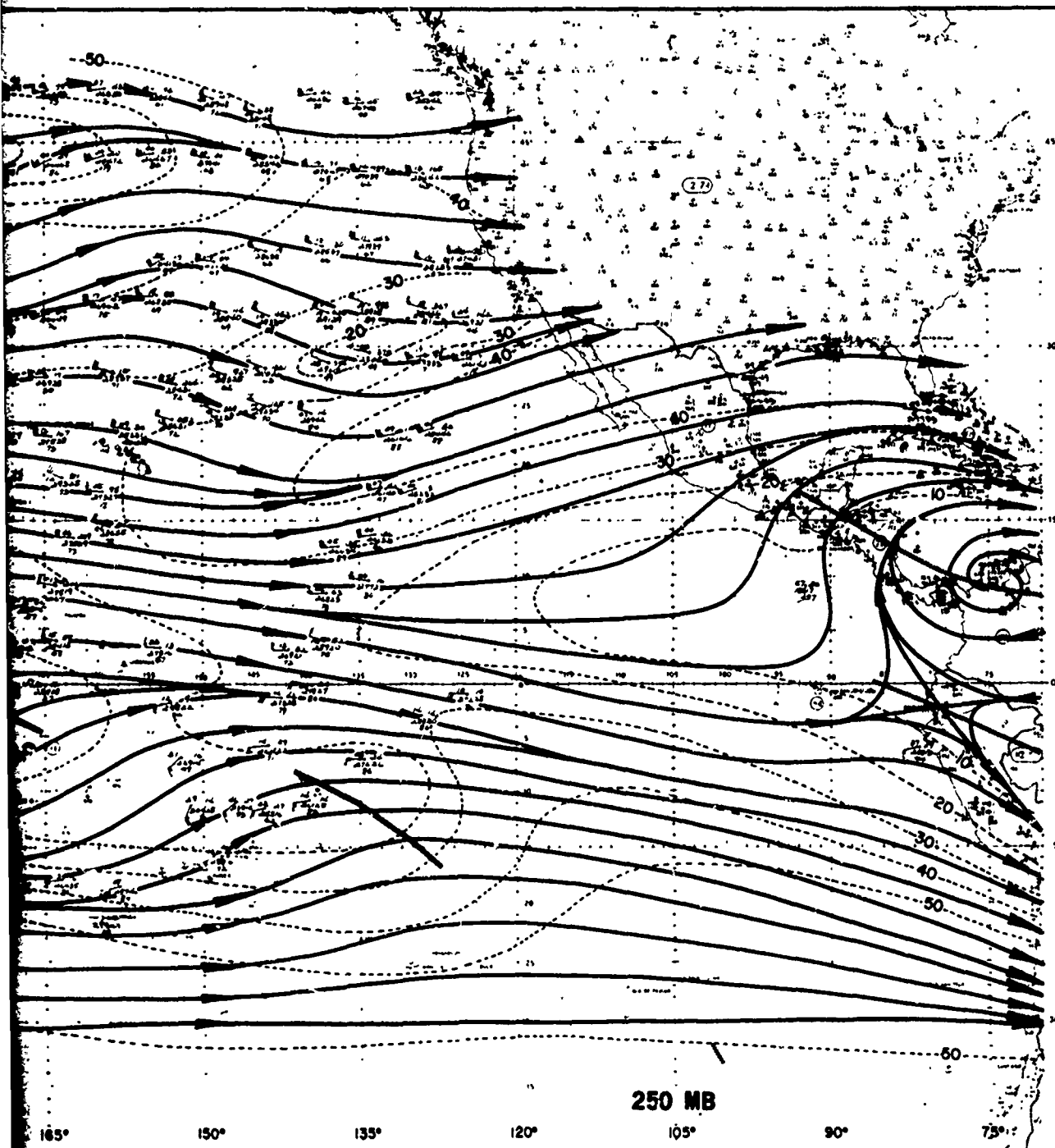
Westerlies have returned to the equatorial strip from 180 eastward to South America. The greatest change has occurred over the eastern Pacific north of the equator where the strong northeast current of summer has disappeared.

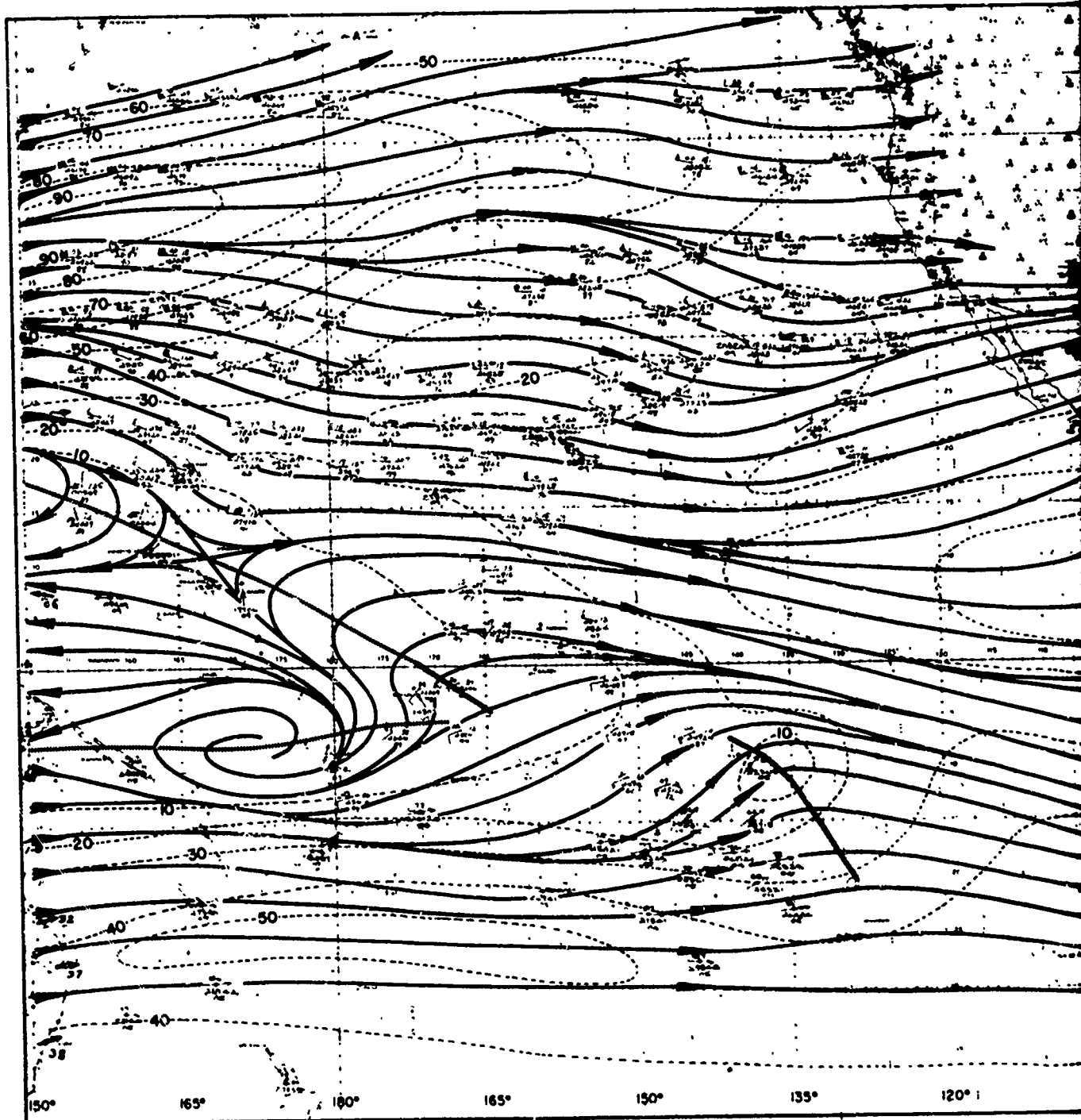
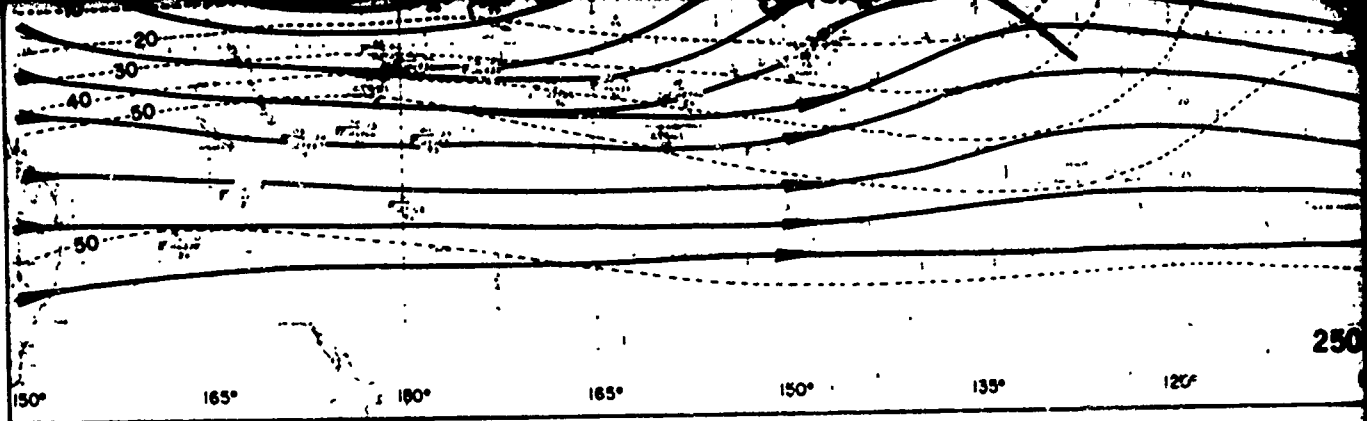
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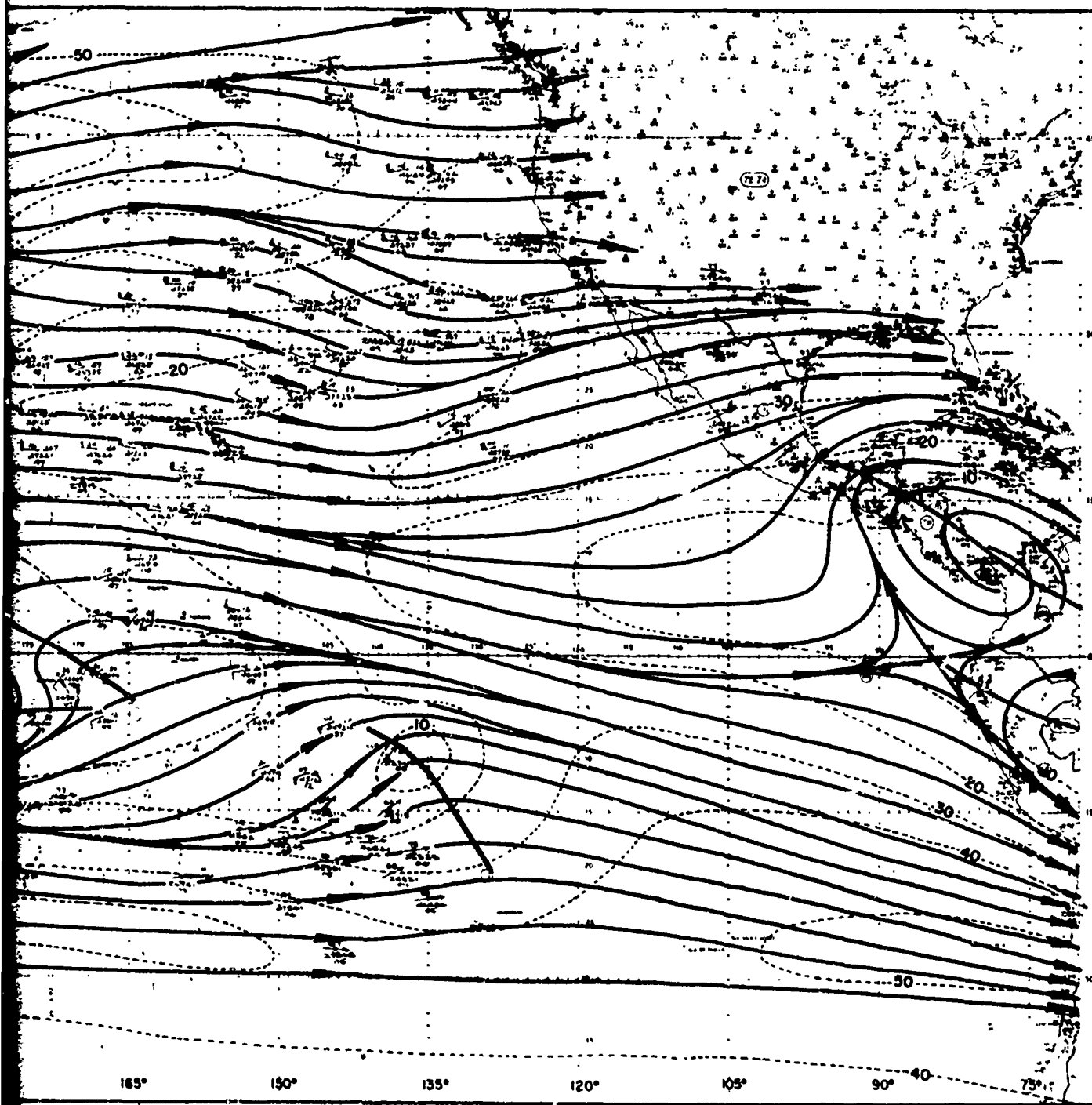
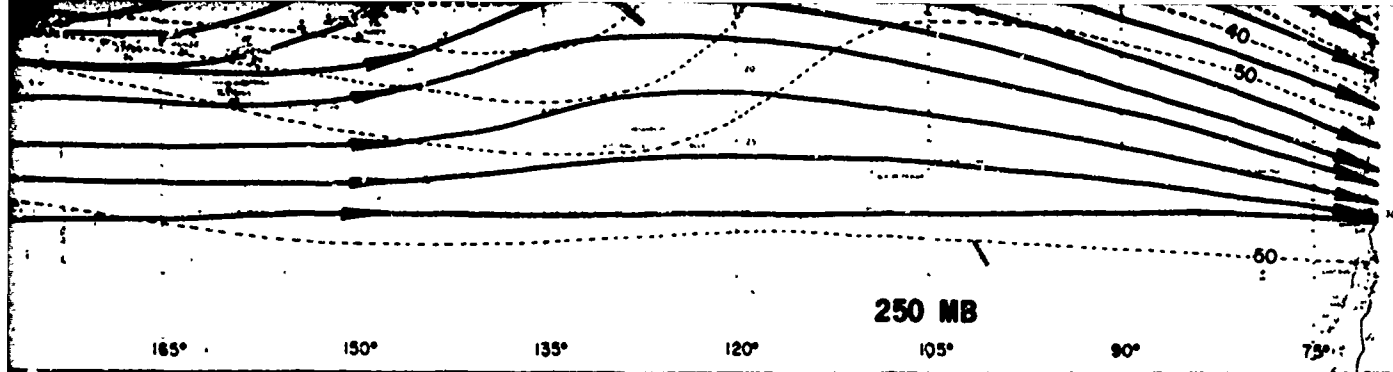
Rawins

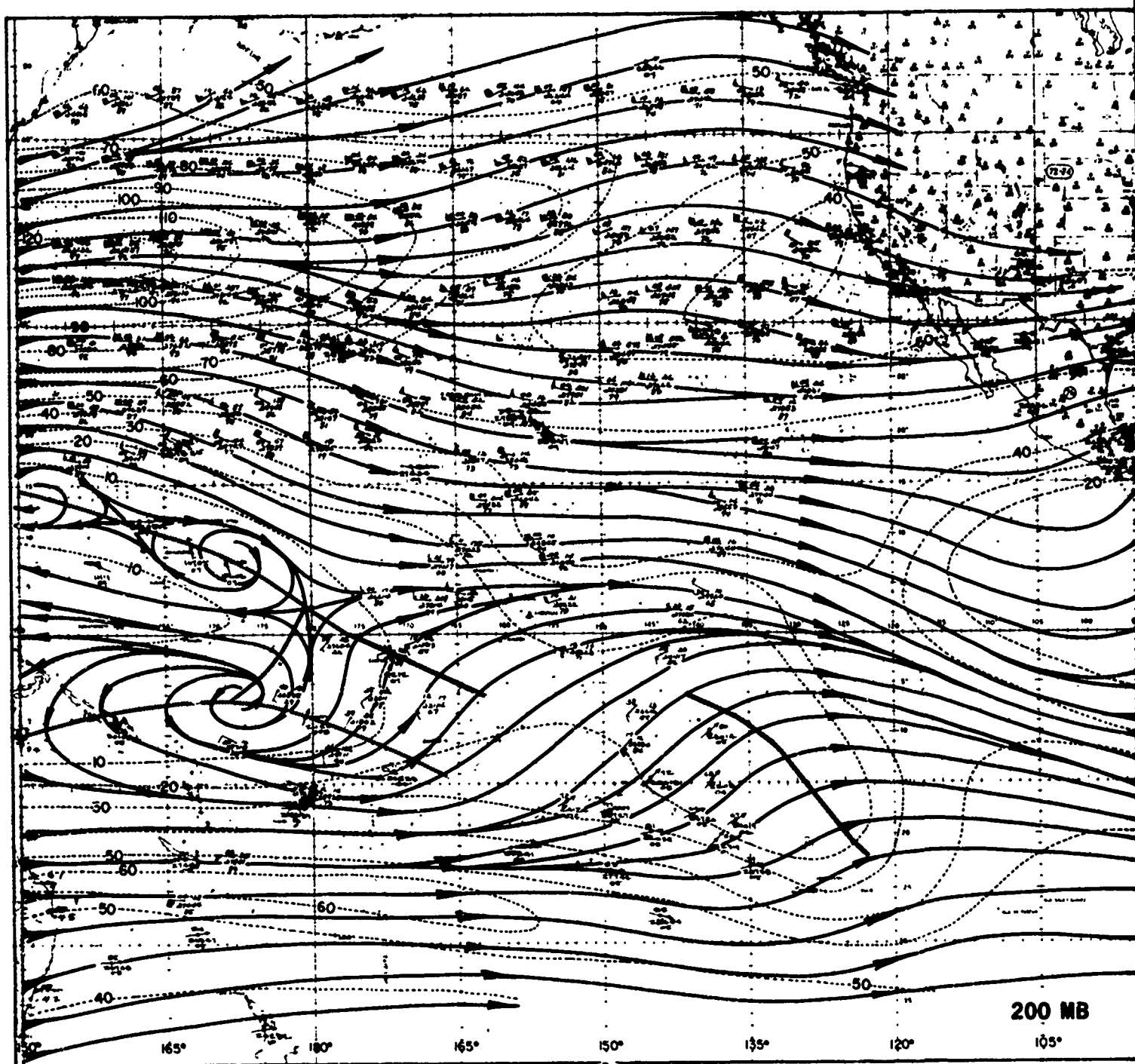
SS

 dddfff
 NN









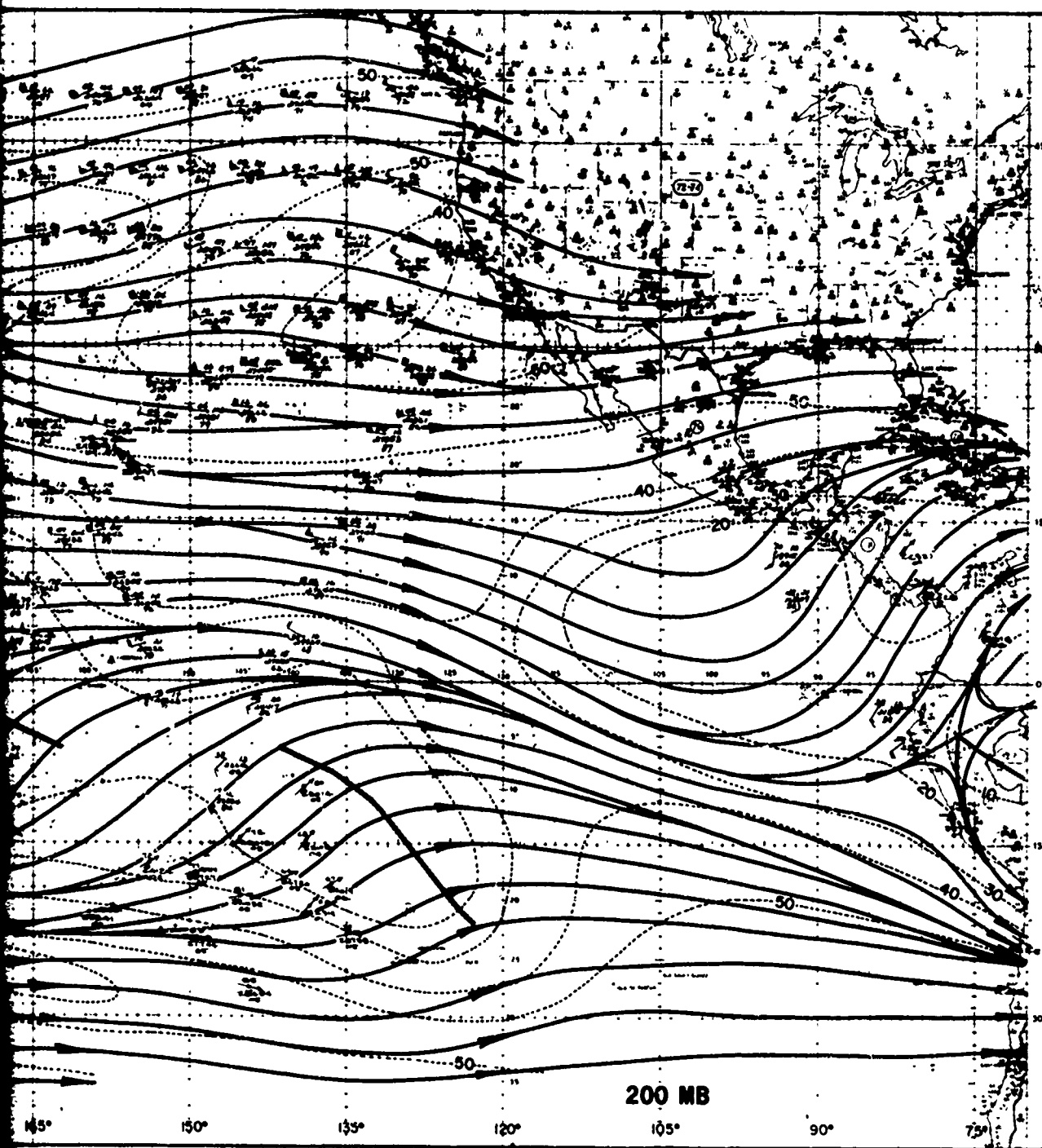


DECEMBER

Northern Hemisphere

The winter pattern has been established. The temperate jet core speeds are near 130 kt. The current branches downstream. The southernmost branch of greater than 50 kt passes north of Hawaii and across Baja California. The northern branch crosses the Washington coast north of 45°N.

Southern Hemisphere

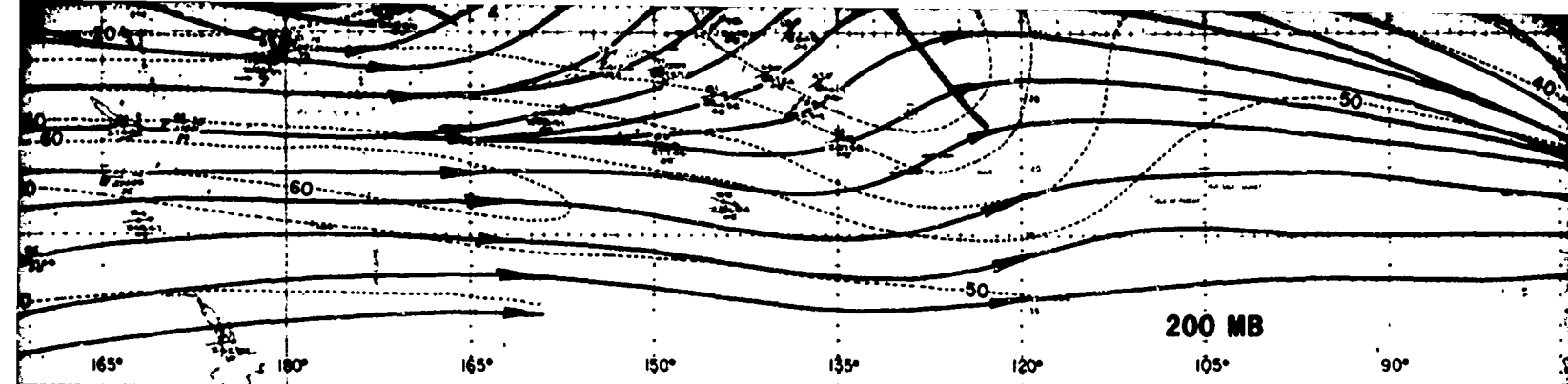


DECEMBER

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DECEMBER

Northern Hemisphere

The winter pattern has been established. The temperate jet core speeds are near 130 kt. The current branches downstream. The southernmost branch of greater than 50 kt passes north of Hawaii and across Baja California. The northern branch crosses the Washington coast north of 45N.

Southern Hemisphere


The temperate westerlies have decreased slightly from November.

The TUTT has intensified; however, it appears, from the very meager data between 150W and 165W, that it is still segmented.

Equatorial Region


The westerlies have increased from November.

PIREP Winds

EE nnnn

 dddfff
 SS

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SS

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